TECHNICAL MEMORANDUM

RESULTS OF HANOVER/WHITEWATER CREEK PHASE I RISK-BASED ANALYSIS

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EXECUTIVE SUMMARY

This technical memorandum documents the results of statistical and risk assessment analyses of Phase I sediment data collected in the Hanover/Whitewater Creek (H/WC) Investigation Unit (IU). These analyses supplement data assessments in the Phase I Remedial Investigation (RI) Report (GAI, 2000). The methods and results are provided for a screening risk assessment, exploratory data analysis, a preliminary risk assessment, and uncertainty and sensitivity analyses.

The H/WC IU was divided into three exposure reaches (E1–E3) for the screening risk assessment, where each exposure reach encloses an area of relatively similar potential or actual land use. The IU was further divided according to the three prevalent geomorphic features in the stream system: overbanks, bars, and the active channel. Of the three exposure reaches described in the Human Health Risk Assessment Work Plan (N&C, 1999), the first exposure reach (E1, from Highway 152 to the junction of Whitewater Creek and Lake One) is where human health impacts are likely to be greatest. The metals of greatest potential concern for human health risk are arsenic, copper, iron, lead, manganese, and zinc.

Statistical analysis of the Phase I data from E1 shows that particle size has a significant influence on metals concentrations for all three geomorphic feature types. Additionally, overbanks show a significant influence of sample depth upon metals concentrations, unlike the bars and active channel. Overbanks also differed from bars and active channel with respect to correlations between the concentrations of metals. Twelve of 15 possible correlations between metals in the overbanks were statistically significant. The active channel data had three significant correlations and the bars data had four significant correlations. Metal concentrations in all three geomorphic features were found to be highly variable, indicating that the available data for these metals cannot be used to estimate metals concentrations in unsampled geomorphic features.

The preliminary risk assessment was conducted to establish approximate risk values for E1 using residential and recreational land use conditions and reasonable maximum exposure (RME) assumptions. Sediment data for the six metals identified as potential risk drivers in the screening risk assessment were analyzed to develop distributions of exposure concentrations pertaining to the entire area of E1. Chemical hazard indices (HI) and cancer risk were highest for hypothetical residents living on overbanks; HI was approximately 20 and cancer risk was 4×10^{-4}. Cancer risk and HI were lower for potential exposure to metals in bars and the active channel (HI values of approximately 2–6 and cancer risks of 3 to 5×10^{-5}, depending on the land use scenario employed). The results of the preliminary risk assessment indicate that cancer risk and HI estimates are likely to be near or above their respective threshold criteria of one for HI and 10^{-6} to 10^{-4} for cancer risk.

The effect of uncertainty in the exposure inputs to variables used in the preliminary risk calculations was evaluated by calculating residential risk estimates using both central tendency exposure (CTE) and RME assumptions. The difference between the RME and CTE cancer risk estimates was approximately a factor of 30, while differences in HI were only about a factor of four. The chicken and egg ingestion exposure pathways were identified as the dominant factors in the magnitude of both the cancer risk and hazard quotient estimates. Uncertainty in the values of plant-soil concentration ratios, particularly the ratio for arsenic, was also a major contributor to uncertainty in the estimated risk. The relative contribution of ambient metal concentrations to chemical hazard and cancer risk in the preliminary risk assessment and uncertainty analysis is unknown because a data set of representative background metals concentrations for H/WC soils and sediments is not presently available.

The results of these analyses indicate that the most pressing data needs to improve risk-based decisions for the H/WC IU are concentrations of metals in eggs, chicken meat, and produce raised on-site. Information on background concentrations of metals within the IU is also necessary to identify the boundaries of mining-related contamination and to differentiate site-related risks from background risk levels.

CONTENTS

Attachments

Figures

Tables

1.0 INTRODUCTION

Project Background

Chino Mines Company (CMC) and the New Mexico Environment Department (NMED) met on March 8 and 9, 2000, to discuss NMED comments on the December 17, 1999, version of the Phase I Remedial Investigation Report, Hanover and Whitewater Creeks Investigation Units (H/WC IU) (GAI, 1999). At this meeting, CMC and NMED representatives concurred that NMED would produce a technical memorandum that included the results of risk-based uncertainty and sensitivity analyses using the H/WC risk assessment model, and that incorporated the results of data analysis to be documented in a revision of the December 17, 1999, Phase I RI Report.

This technical memorandum is part of an ongoing site characterization and human health risk assessment effort for the H/WC IU. The Hanover Creek and Whitewater Creek Investigation Units are defined in an Administrative Order on Consent between CMC and the NMED. As described in the Phase I RI Proposal for the H/WC IU (DBS and GAI, 1998), the H/WC investigation is proceeding in two phases. The goal of Phase I activities is to support an evaluation of the effect of physical processes in the stream system on contaminant distribution in the IU. With such information, preliminary estimates of the mean and variance of metal concentrations that correspond to both physical strata and potential exposure areas may be developed. The goal of Phase II activities is to collect any additional information that may be necessary to reduce uncertainties in the risk assessment (and associated risk-based decisions) to levels acceptable to the risk managers.

Objective and Scope of the Memorandum

The objective of this document is to identify those pathways and parameters that contribute most to the magnitude and variability of estimates of chemical hazard and cancer risk for the H/WC IU. Both the Phase I RI Report and these analyses will be used to support planning for Phase II data collection for the H/WC IU.

There are four sequential evaluations presented in this Technical Memorandum to achieve this objective. These are: 1) a risk-based screening assessment of maximum contaminant values, 2) analysis of Phase I sediment data to estimate exposure point concentrations and to evaluate correlations among metals concentrations, 3) a preliminary risk assessment, and 4) uncertainty and sensitivity analyses of the input parameters for the risk assessment. The purpose of each of these evaluations, and their relationship to the objective of the memorandum, is summarized below.

Risk-Based Screening: Maximum detected concentrations from the Phase I sediment data are compared with protective risk-based screening criteria developed for the H/WC IU. The purpose of this screening is to identify those metals present at concentrations that are potentially significant with respect to human exposure. The screening results are used to focus data analysis activities to those metals that are of greatest potential human health concern.

Phase I Sediment Data Analysis: The spatial distribution of metal concentrations in site sediments, and the relationship of metal concentrations to variables such as particle size, depth, geomorphic feature, location in the H/WC drainage, and concentration of other metals, is described. The purpose of these analyses is to develop appropriate estimates of average metal concentrations, and variability in concentrations, to support the preliminary risk assessment and uncertainty / sensitivity analysis.

Preliminary Risk Assessment: A preliminary risk assessment was conducted using estimates of average metal concentrations from the Phase I sediment data analysis. The purpose of this assessment is to establish the approximate magnitude of potential site risks so that the value of reducing uncertainty in the risk estimates is understood. If the preliminary risk assessment indicates that potential site risks are either vastly greater or less than decision thresholds, then there may be little value in obtaining additional information to refine the risk estimates.

Uncertainty and Sensitivity Analysis: An uncertainty analysis was conducted to evaluate the confidence associated with the results of the preliminary risk assessment. Many of the inputs to a risk calculation are estimates, not precise values. An uncertainty analysis uses ranges for these inputs in order to determine what happens to the risk estimate when the inputs to the equation change. The sensitivity identifies which specific exposure variables were responsible for the majority of uncertainty in the risk estimate. The uncertainty and sensitivity analyses combined provide information on the degree of confidence associated with the preliminary risk estimates, and which specific exposure variables should be targeted in order to develop a more accurate risk estimate with a higher level of confidence.

Conceptual Site Model

The evaluations performed in this memorandum were conducted in the context of the physical site model (described in the Phase I Remedial Investigation Proposal [DBS and GAI, 1998], Human Health Risk Assessment Work Plan [N&C, 1999] and Phase I Remedial Investigation Report [GAI, 2000]) and exposure model (described in the Human Health Risk Assessment Work Plan [N&C, 1999]). Collectively, the physical and exposure site models describe the key processes and features that control contaminant migration within the IU, and how and where humans may be exposed to these contaminants. A summary of these models is provided here to facilitate understanding of the information provided in this memorandum.

The length of the Hanover/Whitewater Creek system between the crossings of Highways 152 and 180 and is approximately 17 miles. The creek system has been divided into a series of nine "physical reaches" (P1–P9) for the site investigation. These physical reaches are based on various criteria including channel and floodplain characteristics, the proximity to contaminant sources, and the influence of major tributaries. Contaminant sources within the IU include releases associated with mineral processing activities such as the Precipitation and SX/EW Plants, dewatering discharges from mining shafts, releases from stockpiles and tailing ponds, and contaminants associated with other mines such as Blackhawk and Bullfrog.

In the past, water flow associated with intentional or accidental releases from CMC operations has been a major source of contamination to the stream channel. With the issuance of a zero-discharge operating permit for the mine, contaminant redistribution in the IU became principally controlled by surface flow resulting from storm events. Sediment redistribution occurs during infrequent high-energy flow events. The character of the stream channel and overbanks reflect patterns of sediment mobilization and deposition. Within the IU, distinct geomorphological features exist that reflect the history of these processes.

Three potentially impacted geomorphological features (the active stream channel, point and mid-channel bars, and overbanks) form the physical basis of sediment sampling in the IU. Because both the volume and metal concentrations of stream flows have varied with time, the sediments that comprise geomorphological features deposited at different times harbor different levels of metal contamination. Furthermore, different types of features have different relative amounts of fine and coarse-grained sediments. Higher metal concentrations are typically associated with smaller particle sizes.

The human exposure model was developed to support the sediment sampling design by identifying land use and human behaviors that may impart significance to specific physical features, locations, and spatial scales in the environment. By defining the potentially exposed populations (e.g., receptors) and the ways in which exposure may occur, an approach for sample collection was devised that generated appropriate data for the risk assessment. Just as the stream channel was subdivided into physical reaches, as described above, it was also divided into exposure reaches based on criteria including actual and/or potential land uses and accessibility. These exposure reaches include the following:

- **Exposure Reach 1:** Hwy. 152 to the junction of Whitewater Creek with Lake One;
- **Exposure Reach 2**: the two artificial channels and one natural channel between the junction of Whitewater Creek with Lake One and the southeast corner of Tailing Pond 7; and
- **Exposure Reach 3**: the natural channel from the southeast corner of Tailing Pond 7 to the southern boundary of the AOC.

Four different exposure scenarios were defined to assess potential exposure of receptors to contaminated sediments. These scenarios include the following:

- **On-Site Residential**: residential receptors living adjacent to the stream channel;
- **Off-Site Residential**: residential receptors who have transported channel/overbank sediments for use as fill at a remote homesite;
- **Recreational / Resource Use**: receptors who use the IU for hiking or similar activities, or for grazing cattle or gathering uncultivated plant materials; and
- **Trespasser**: receptors who have trespassed in areas of the IU owned by CMC where access is actively restricted.

Each of the four exposure scenarios is associated with specific exposure pathways, which constitute ways in which receptors are potentially exposed to contaminants in IU sediments. These exposure pathways include the following:

- **Soil Ingestion**: soil adhering to the skin, food, or other objects is inadvertently swallowed;
- **Dust Inhalation**: suspended soil particles are inhaled and trapped in the lungs;
- **Produce Ingestion**: fruits and vegetables raised in a home garden absorb metals from contaminated soil, incorporate the metals in their tissues, and are eaten;
- **Chicken and Egg Ingestion**: poultry take in metals from ranging on contaminated soil, incorporate the metals in their tissues, and the meat and eggs are eaten;
- **Beef Ingestion**: cattle raised in the IU take in metals from contaminated soil, incorporate the metals in their tissues, and the meat is eaten; and
- **Ingestion of Uncultivated Plants**: wild plants growing on contaminated soils incorporate metals in their tissues, and the plants or their fruits are gathered and eaten.

The relationship among exposure reaches, exposure scenarios, geomorphic features, and exposure pathways is shown in Table 1.

Table 1
Summary of Hanover/Whitewater Creek Human Exposure Model

Scenario Name	Geomorphic Feature	Exposure Reach 1	Exposure Reach 2	Exposure Reach 3
On-site residential*	Overbanks	Soil ingestion, dust inhalation, produce ingestion, chicken and egg ingestion		Soil ingestion, dust inhalation, produce ingestion, chicken and egg ingestion
Off-site residential	Overbanks, bars, active channel	Soil ingestion, dust inhalation, produce ingestion		
Recreational/ resource use	Overbanks, bars, active channel	Soil ingestion, dust inhalation, beef ingestion, ingestion of uncultivated plants		Soil ingestion, dust inhalation
Trespasser	Overbanks, bars, active channel, manmade channel		Soil ingestion, dust inhalation	

*On-site residential exposure in Exposure Reach 3 is evaluated as a potential future land use.

Summary of the Risk Assessment Technical Approach

Human health risk assessment (HHRA) for a site such as the H/WC IU involves four steps. They are 1) data collection and evaluation, 2) contaminant exposure assessment, 3) toxicity assessment, and, 4) risk characterization. The RI phase of an environmental investigation is focused primarily on data collection and evaluation, where the objectives include identifying the contaminants of potential concern (COPCs) for human health and establishing the concentrations of these contaminants in environmental media where receptors may be exposed. The risk assessment process for H/WC is iterative. A Phase I RI was conducted and those data were used for the screening and preliminary risk assessments presented in this document. A Phase II RI is anticipated to fill identified data gaps. Both Phase I and Phase II data will be used to perform a baseline risk assessment.

Uncertainty in human exposure to contaminated media is initially addressed in the HHRA by employing two sets of exposure assumptions. A reasonable maximum exposure (RME) estimate uses protective values for selected exposure variables (such as contaminant concentrations, the ingestion rate of soil particles or foodstuffs, and the length of the exposure period) to calculate exposure rates that are higher than expected. A central tendency exposure (CTE) estimate uses values for exposure variables that represent average conditions. As the difference between CTE and RME exposure estimates increases, so does the likelihood that acquiring additional information may substantially reduce uncertainty and improve risk management decisions. The purpose of evaluating CTE conditions is to provide an approximate measure of the amount of protective bias related to the reasonable maximum exposure assumptions.

The risk assessment calculations for this memorandum are consistent with guidance provided by EPA in *Risk Assessment Guidance for Superfund, Human Health Evaluation Manual, Part A* (EPA, 1989). The use of RME and CTE estimates in this memorandum is consistent with *Guidance on Risk Characterization for Risk Managers and Risk Assessors* (EPA, 1992) and *Risk Assessment Guidance for Superfund: Volume 3 – Part A, Process for Conducting Probabilistic Risk Assessment* (EPA, 2001a). Non-carcinogenic effects for individual chemicals in the uncertainty and sensitivity analyses are expressed as hazard quotients (HQs). An HQ is the ratio of the average daily dose (i.e., chemical intake)

of a chemical to the corresponding reference dose (RfD) for that chemical. Cancer risk in the uncertainty and sensitivity analyses is evaluated as the incremental probability that an individual will develop cancer during their lifetime. An incremental lifetime cancer risk (ICR) is the product of the chemical intake and a slope factor (SF). Input parameter values and risk equations used for the screening risk assessment, preliminary risk assessment, and uncertainty/sensitivity analyses are provided in Attachment 1.

This technical memorandum for Phase I risk-based data analysis is a revision of a draft issued on January 24, 2001. Since the issuance of the first draft, EPA has issued new guidance pertinent to human health risk assessment. In particular, there is more recent guidance for conducting dermal risk assessment (*Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment, EPA, 2001b).* Some equations and parameter values used in this memorandum have been revised from the earlier draft in order to maintain consistency with current guidance.

2.0 SCREENING RISK ASSESSMENT

The purpose of this screening risk assessment is to identify the principal risk-driving metals in order to focus Phase I data analysis on those sections of the H/WC drainage and those metals that are likely to be of most significance in the subsequent risk assessments. The metals selected for evaluation in this memorandum are likely to be the most significant metals in a future baseline risk assessment, although resolution of the uncertainties described in Section 5 may alter this list.

The risk assessment screening was performed on all 21 metals in the H/WC characterization data set using risk-based screening levels (RBSLs) developed based on site-specific exposure models. The RBSLs were calculated using RME exposure assumptions, as described above. The sediment metals data used in this screening were reported in the Phase I RI Report (GAI, 1999).

The maximum reported metals concentration values across all of the three geomorphic features in the exposure reaches is screened against the RBSL value. For Exposure Reach 1 (E1) and Exposure Reach 3 (E3), where multiple exposure scenarios have been developed, the RBSL values are based on on-site residential land use. The Phase I data set used in this screening includes soil and sediment data from both the main streams and tributary canyons that were sampled to evaluate potential sources of contamination to the main streams. The exposure reaches and associated exposure scenarios are presented in Table 1. Table 2 shows the list of metals, RBSL values for each metal, and the maximum values for those metals across active channel, bars, and overbanks. Highlighted values indicate where the maximum detected sediment concentration exceeds an RBSL value. A complete tabulation of scenario-specific screening values for each exposure reach is provided in Attachment 1.

In E1, RBSLs were exceeded for arsenic, chromium, copper, iron, lead, manganese, and zinc. No metals exceeded RBSLs in E2. In E3, RBSLs were exceeded for arsenic, chromium, copper, and iron. In total, RBSL values were exceeded for seven metals.

Table 2
Comparison of Maximum Detected
Metal Concentrations in Sediment to Risk-Based Screening Levels

Chemical	E1 RBSL[a]	E1 Max Value	E2 RBSL[a]	E2 Max Value	E3 RBSL[a,b]	E3 Max Value
Aluminum	54000	28000	unlimited	31000	54000	26000
Antimony	29	16	11000	5	29	5
Arsenic	0.027	**24**[c]	26	5.2	0.027	**2.1**
Barium	1100	240	570000	230	1100	270
Beryllium	64	2.2	4024	1.5	64	1.3
Boron	360	25	990000	7.4	360	7.5
Cadmium	16	15	5361	7.5	16	ND[d]
Chromium	13	**46**	806	45	13	25
Cobalt	1900	99	830000	37	1900	8.5
Copper	550	3300	700000	2700	550	**1100**
Iron	2800	97000	unlimited	78000	2800	**58000**
Lead	400	**1900**	1000	95	400	53
Manganese	890	**4300**	150000	630	890	660
Mercury	0.58[e]	0.26	8100	0.08	0.58[e]	ND
Molybdenum	110	41	130000	81	110	26
Nickel	1100	36	410000	20	1100	20
Selenium	7.9	5.3	130000	3.1	7.9	1.1
Silver	90	14	130000	1.4	90	0.75
Thallium	1.8	1.1	2200	0.25	1.8	0.25
Vanadium	1100	82	210000	36	1100	37
Zinc	660	5700	unlimited	390	660	210

[a] Equations and parameter values related to the RBSL calculations are provided in Attachment 1.

[b] E3 RBSL value based on possible future residential land use.

[c] Bold = The maximum value exceeds the corresponding RBSL.

[d] ND = Not detected.

[e] Mercury value pertains to recreation / resource use exposure scenario.

Chromium exceeded its RBSL value in E1 and E3 by a factor of three and two, respectively. Chromium may occur in sediments in two oxidation states. Chromium^{+3} is more common and is not classified by EPA as a human carcinogen. Chromium^{+6} is typically assumed to be less prevalent than chromium^{+3} under most environmental conditions and is a known human carcinogen. The Cr RBSL is based on the carcinogenicity of Cr^{+6}, (assuming a 6:1 ratio of Cr^{+3} to Cr^{+6}). Another carcinogenic metal in H/WC is arsenic. The maximum concentration of arsenic in E1 exceeds its RME RBSL by a factor of almost 800, and in E3 by a factor of almost 80. Under these conditions, potential cancer risks in the H/WC IU will likely be driven by arsenic sediment concentrations. Therefore, chromium is not included with the remaining six metals as a target metal for data and uncertainty analysis in this memorandum. However, pending information on background concentrations of arsenic and chromium for the H/WC IU, the incremental risk related to chromium may still be significant and will be evaluated in a future baseline

risk assessment. Based on the results of the risk assessment screening, E1 was targeted as the exposure reach in which to focus data and uncertainty analysis for arsenic, copper, iron, lead, manganese, and zinc.

3.0 PHASE I SEDIMENT DATA ANALYSIS

The Phase I soil and sediment samples were collected to evaluate differences in metals concentrations among particle size classes (<63 μm, <250 μm and 250–2000 μm), sample depths (0–6 in. and 6–24 in.) and geomorphic features (overbanks, bars, active channel). The data include soil and sediment concentration values for the 21 metals listed in Table 2. The initial hazard and risk screening is reported in Section 2. The analyses in this section are restricted to the six metals that were identified as potential risk drivers in the screening risk assessment and do not include data from samples collected in tributary canyons.

The Influence of Particle Size and Sampling Depth on Metals Concentrations

The purpose for analyzing the effect of particle size and depth on metal concentrations was to determine the set of data that should be used to evaluate potential chemical hazard and cancer risk. If statistically significant differences in metal concentrations exist between particle size fractions, then the smaller size fraction data is used in the exposure calculations because dust inhalation and soil ingestion are associated with smaller particle sizes. Where statistically significant differences in metal concentrations exist with sample depth, the surface sample data are used, because exposure is more likely with surface soils. If significant differences were not found, then the data were combined to take advantage of a larger sample size for data summaries and statistical analyses.

Table 3 presents a summary of the results for comparisons of metals concentrations between different particle sizes and between samples from different depths. Detailed statistical testing results are provided in Attachment 2. Table 3 shows that particle size has a significant influence on metals concentrations for all three geomorphic feature types. Overbanks also show a significant influence of sample depth upon metals concentrations. Bars and active channel do not show differences with depth, suggesting that these features are better mixed within the depth interval sampled. Exceptions are manganese, which is homogeneous for depth and particle size in the overbanks, and iron which shows no change in concentration with depth in the overbanks and a trend with depth in the active channel. The last column in Table 3 shows the subset of data that is used for additional statistical analyses. These subsets result from the comparisons between particle sizes and depths.

Correlations Between Metals

Evaluations of the characterization data to this point have considered metals concentrations relative to human health risk screening values (Table 2) and the effects of particle size and depth upon metals concentrations (Table 3). Since there are six metals of potential concern for H/WC, the question of how concentrations of each metal are related to the other metals becomes important. This is because exposure to soil or sediment integrates the individual metals concentrations in the soil or sediment in the area where one is exposed. If two metals are positively correlated then exposure to a high concentration of one metal in a certain location will be accompanied by exposure to a high concentration of the other metal. Consequently, the correlation between concentrations of the two metals should be considered when developing potential exposure areas for assessing risk. This particularly important if the toxicity of the two metals is related to effects on the same organ because the toxic effects may be additive or even synergistic.

Table 3
Summary of Comparisons: Metals Concentrations by Particle Size and Depth

Analyte	Does concentration differ with particle size?		Does concentration differ with depth?		Data for Statistical Analyses
	Surface Samples <250µm vs. 250–2000 µm	Deep Samples <250µm vs. 250–2000 µm	<250µm Samples Surface vs. Deep	250–2000µm Samples Surface vs. Deep	
Overbanks					
Arsenic	*[a]	NS[b]	*	*	Surface <250 µm
Iron	*	*	NS	NS	<250 µm
Manganese	NS	NS	NS	NS	All Data
Zinc	*	*	*	*	Surface <250 µm
Lead	*	*	*	*	Surface <250 µm
Copper	*	*	*	*	Surface <250 µm
Bars					
Arsenic	*	*	NS	NS	<250 µm
Iron	*	*	NS	NS	<250 µm
Manganese	*	*	NS	NS	<250 µm
Zinc	*	*	NS	NS	<250 µm
Lead	*	*	NS	NS	<250 µm
Copper	*	*	NS	NS	<250 µm
Active Channel					
Arsenic	*	NS	NS	NS	<250 µm
Iron	*	*	*	*	Surface <250 µm
Manganese	*[c]	*	NS	*	<250 µm
Zinc	*	*	NS	NS	<250 µm
Lead	*	*	NS	NS	<250 µm
Copper	*	*	NS	NS	<250 µm

[a] An asterisk indicates statistical significance ($p \leq 0.05$).

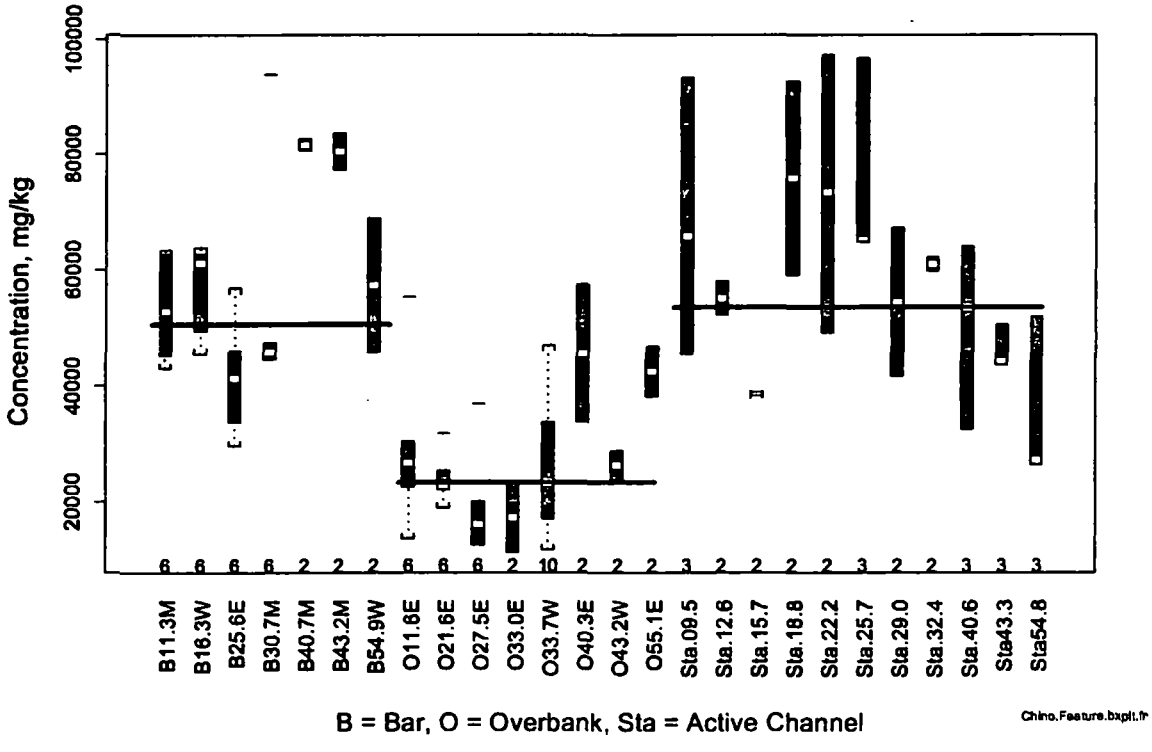
[b] NS = Not significant.

[c] The p-value is 0.083. Concentration is significantly different in the deep samples and there is no difference between surface and deep samples within the <250-µm fraction ($p = 0.266$). Consequently, the difference is treated as significant.

Correlations among arsenic, copper, iron, lead, manganese, and zinc have been evaluated for the <250 µm size fraction samples from surface soils and sediments. The results are presented in Table 4 and a description of the method used to generate the correlations is provided in Attachment 2. Values in Table 4 that are significantly different from zero are in bold typeface.

estimating contaminant concentrations in areas between the sample locations. The Phase I characterization data can be used to evaluate this idea for the H/WC IU by comparing metals concentrations in individual geomorphic features of a given type to determine if there is a consistent pattern in the concentrations. As an example, if all the sampled overbanks have similar concentrations of copper or the copper concentrations change downstream in a regular manner, then there is a rationale for using the existing sediment data for copper to estimate copper concentrations in the overbanks that have not been sampled.

The Phase I characterization data were investigated for trend and variability within and between geomorphic features. Figures 1–3 show boxplots of the data organized by feature type (bar, overbank, active channel), and location within the Hanover-Whitewater Creek drainage system. Boxplots summarize the data by showing a box that includes the middle 50% of the data with a small window that shows the location of the median. The whiskers that extend from the box extend to staples that show the range of the middle 98% of the data. If there are extreme values beyond the staples, they are represented by short horizontal lines. The total number of samples for each boxplot is provided on the x-axis. Manganese, iron and arsenic are presented since the screening risk assessment indicates these metals have concentrations well above their screening levels. The distance reference point for the x-axis is located in the vicinity of Tailings Pond One and James Canyon. The values increase upstream and decrease downstream from that point. The feature labels on the x-axis include distance references in thousands of feet. As an example, "B11.3M" is a bar located 11,300 feet from the reference point in the middle of the channel. Three horizontal lines are placed on each plot representing the median metal concentrations for each geomorphic feature. The first two sampling locations of bars, overbanks, and active channels shown in Figures 1–3 are in the Hanover Creek drainage, the remaining locations are downstream of the Hanover and Whitewater Creeks confluence.



Note: Horizontal lines are group medians, numbers below boxplots are sample size

Figure 1. Iron concentrations in bar, overbank, and active channel features

Table 4
Spearman Rank Correlation Coefficients for Metals in Overbanks, Bars, and Active Channel

Overbanks						
	Arsenic	Iron	Manganese	Zinc	Lead	Copper
Arsenic	1.00					
Iron	**0.69**[a]	1.00				
Manganese	**0.67**	**0.70**	1.00			
Zinc	**0.81**	**0.74**	**0.82**	1.00		
Lead	**0.85**	**0.69**	**0.88**	**0.83**	1.00	
Copper	**0.51**	0.16	0.18	0.37	**0.48**	1.00
Bars						
	Arsenic	Iron	Manganese	Zinc	Lead	Copper
Arsenic	1.00					
Iron	-0.14	1.00				
Manganese	0.40	0.32	1.00			
Zinc	0.39	0.16	**0.84**	1.00		
Lead	**0.63**	-0.24	0.17	0.09	1.00	
Copper	0.21	0.13	**0.77**	**0.68**	0.21	1.00
Active Channel						
	Arsenic	Iron	Manganese	Zinc	Lead	Copper
Arsenic	1.00					
Iron	0.28	1.00				
Manganese	-0.01	-0.53	1.00			
Zinc	0.05	-0.55	**0.99**	1.00		
Lead	-0.10	0.48	0.04	0.08	1.00	
Copper	**0.59**[b]	**0.70**	-0.04	-0.04	0.34	1.00

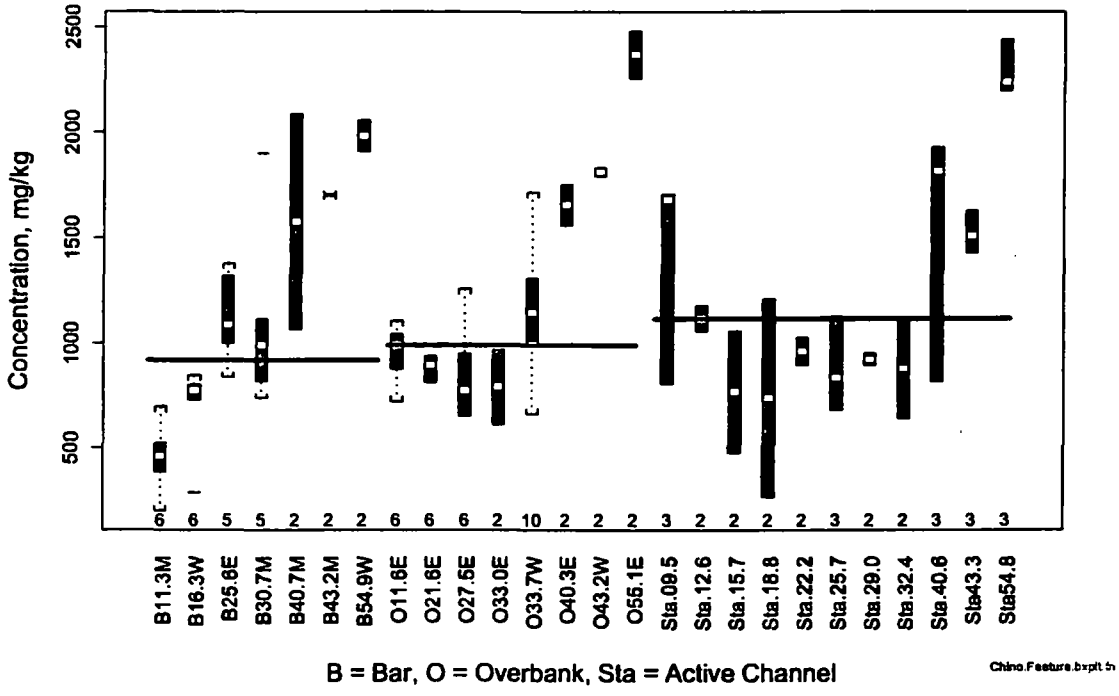
[a] Bold = Correlation is significantly different from zero, $\alpha = 0.05$.

[b] $p = 0.063$.

These correlations suggest that the overbanks have a spatial structure to them such that relatively high values for one metal tend to be associated with higher values of the other metals. Twelve of the fifteen possible correlations among metal concentrations are significant for the overbanks. In contrast, the bars and active channel show less correlation structure, with four significant correlations for the bar data and three significant correlations for the active channel. Some of the apparent correlations for the active channel may be partially caused by downstream trends in metal concentrations.

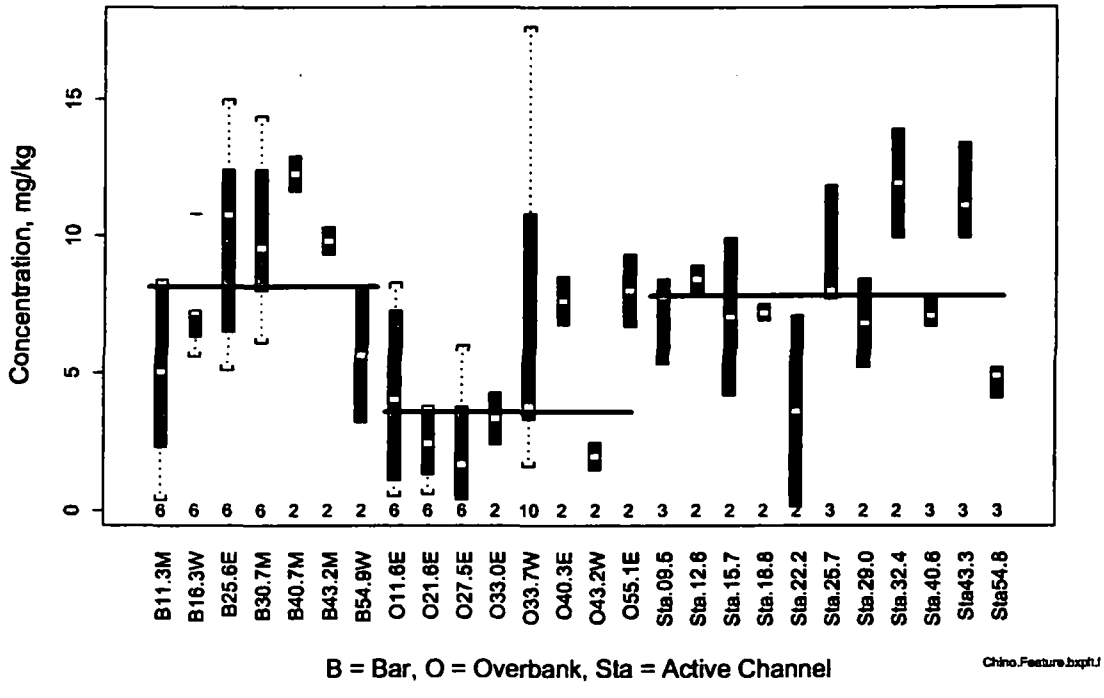
Changes in Metals Concentrations Among Individual Geomorphic Features

Data analyses to this point have addressed overall characteristics of soils and sediments based upon individual samples. Results are presented for particle sizes, sampling depths, and correlations among metals concentrations. Another question that is important to overall characterization of the H/WC IU is how well the data represent areas that have yet to be sampled. A basic idea in environmental characterization is that a sampling design can be developed that will provide data that are useful for



Note: Horizontal lines are group medians, numbers below boxplots are sample size

Figure 2. Manganese concentrations in bar, overbank, and active channel features



Note: Horizontal lines are group medians, numbers below boxplots are sample size

Figure 3. Arsenic concentrations in bar, overbank, and active channel features

All three feature types show variability to the extent that treating these data as coming from a single statistical population is not advised. This also means that the available data for these metals cannot be used to estimate metals concentrations in unsampled geomorphic features. The bars show a decreasing trend for arsenic and manganese within Whitewater Creek. The two most distant bars, B43.2M and B54.9W in Hanover Creek, show lower values for arsenic and higher values for manganese. Iron is also highly variable, but a distance pattern is not evident. Overbanks show some stability in concentrations below O33.0E with higher and more erratic values upstream. The data for O33.7W is troubling because it shows that overbank to be the most variable and it is also the overbank with the most samples. It is possible that apparent differences in metals concentrations within and among the overbanks is due to insufficient data to represent the metals concentrations in the features. The active channel data show a noisy decreasing trend for arsenic and manganese and an increasing trend for iron with distance downstream.

Characterization Data Summaries

The results of the assessment of differences in key metal concentrations with particle size and depth, and correlations among metals, were used to develop data sets for the risk-based analyses described in Sections 4 and 5. Summary statistics from these data sets for each of the key metals are provided in Table 5. The last column provides the number of results that were used to calculate the summary statistics. The number depends upon the particle size and depth analysis reported earlier. The median value is the middle value of the data such that half the data are larger and half the data are smaller than the median. The log mean value is the average of the logarithms of the data that has been transformed back to original measurement units. This is a method for estimating the average of a data set that has more small values than large values. Upper confidence limits (UCLs) are presented for the median and for the log mean. If the many samples were collected and randomly assembled into groups with the number of samples in a group equal to the last column of the table, each group would have a different median and log mean. This is because each group median or log mean is an estimate of the true (unknown) value for the overbanks, bars, or active channel. The UCL is a statistically derived value used as a protective upper bound estimate of the true median or mean. In our case the UCL indicates that if many medians or log means were calculated for the H/WC basin, 95% of them would be less then or equal to the UCL.

Particle Size Consequences to Risk Assessment

The first analysis in this section demonstrated that there are statistically significant differences in metals concentrations associated with difference particle sizes in the stream sediments and overbank soils of H/WC. The final question in this section addresses whether these statistical differences are meaningful in a risk assessment context. Although EPA's Risk Assessment Guidance for Superfund (EPA, 1989) lists particle size among those soil and sediment parameters for which information may be required, in practice soil samples are generally sieved in the analytical laboratory through a 2 mm screen. The value of 2 mm originates from U.S. Department of Agriculture definitions of soil particle size; 2 mm is the size where coarse sand is differentiated from gravel. The choice of 2 mm as the upper bound of soil particle size has no specific basis in human health exposure assessment.

Table 5
Summaries of the Metals Data Used for the
Preliminary Risk Assessment and Uncertainty and Sensitivity Analyses

Analyte	Min	Median	Median UCL	Log Mean	LogMean UCL	Max	n
Overbanks							
As	0.43	3.82	6.7	5.27	9.39	14.2	19
Fe	12500	23600	30500	27400	31900	57400	30
Mn	402	1000	1170	1230	1350	2790	72
Zn	161	865	1360	1140	1960	5160	19
Pb	33.2	155	294	226	376	657	19
Cu	196	938	1440	1110	1610	3250	19
Bars							
As	0.37	8.15	10.4	9.13	12.3	15.	30
Fe	29700	50600	62600	55800	61200	94000	30
Mn	199	918	1320	1240	1640	4300	30
Zn	142	720	1310	1090	1580	3780	30
Pb	107	264	305	304	348	722	30
Cu	310	677	822	787	946	2250	30
Active Channel							
As	0.15	7.80	8.4	9.11	13.30	13.9	27
Fe	26400	45600	59100	46700	55300	64700	11
Mn	264	1120	1510	1260	1540	2440	27
Zn	226	1050	1330	1300	1760	3730	27
Pb	135	266	297	288	320	496	27
Cu	269	612	669	628	699	1160	27

The soil ingestion pathway is primarily governed by hand-to-mouth contact. Research suggests that the upper limit of particle size adhering to the hands is on the order of a few hundred microns (Kissel et al., 1996; Duggan and Inskip, 1985). Therefore, metal concentrations associated with the 0–250 μm particle size fraction are most appropriate for use in quantifying risks via soil ingestion and dermal absorption. For inhalation, a cutoff value of 10 μm for particle diameter (PM_{10}) has been traditionally applied for ambient air sampling and is the basis of EPA standards for airborne particulates. The smallest size fraction obtainable by dry sieving (63 μm) can be used as a surrogate for PM_{10}.

The research cited above indicates the approximate particle sizes that are important for exposure via soil ingestion and dust inhalation. A site specific consideration is whether contaminant concentration changes with particle size enough to warrant collecting and analyzing smaller size fractions to support risk assessment. Phase I characterization data were collected within three particle size fractions; 0–63 μm, 63–250 μm, and 250–2000 μm.

The effect of particle size on contaminant concentration is shown in Table 6 for three metals of concern at this site; arsenic, iron, and manganese. Arsenic and iron show increased concentrations in the smaller particle size fractions, while manganese shows little change in concentration across the analyzed particle sizes. Most of the metals in the H/WC Phase I data had particle size relationships consistent with arsenic

and iron. Manganese is an exception; the manganese results indicate that manganese concentrations are related to the parent rock material and not due to contaminant sorption to particle surfaces. Although Table 6 was created using only overbank samples, similar relationships were observed in the other geomorphic features using 0–250 μm and 250–2000 μm size fractions.

Table 6
Average Contaminant Concentration (mg/kg) for Three Particle Size Fractions

Analyte	0–63 μm	63–250 μm	250–2000 μm
Arsenic	7.1	3.8	3.1
Iron	42,000	30,000	27,000
Manganese	1,500	1,400	1,600

Figure 4 shows the relative proportion of particles in three size fractions in each of the three geomorphic units. This figure shows that the percent mass of the 250–2000 μm size fraction remains relatively constant among the geomorphic features, while the mass of fine particles is proportionally larger in overbanks than in the stream channel.

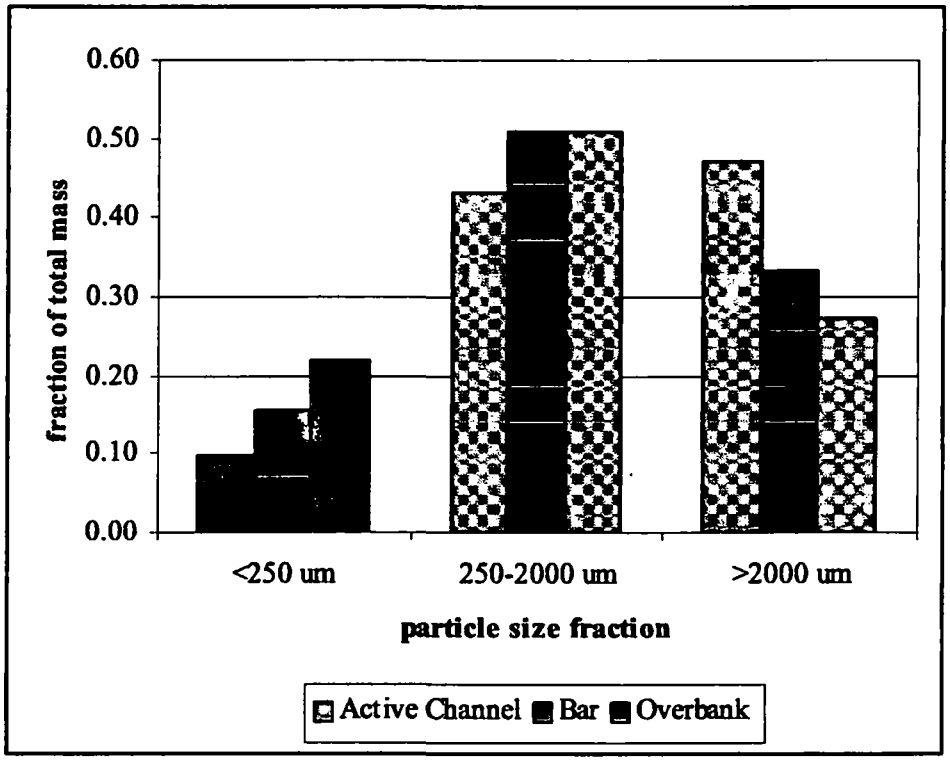


Figure 4. Particle size fraction distribution among geomorphic features

The information in Table 6 encourages a more in-depth analysis of the data. A typical approach is to use statistical methods that take advantage of all the data, instead of just the averages, in order to develop concentration relationships among the particle size classes. The Phase I data for arsenic, iron, and

manganese were evaluated with regression analysis in order to determine relationships among particle size fractions and metal concentrations. The metals concentration data for the smallest particle size fraction (0–63 µm) were evaluated relative to the metals concentration data for each of the other fractions, (63–250 µm, 250–2000 µm, and composite 0–2000 µm). The result was evaluated using a comparison between the total variability in the data versus the amount of variability that is explained by the relationships among the particle size classes. For arsenic and iron, the amount of variability in concentration due to particle size was from 83 to 98% of the total variability. The manganese results were consistent with Table 6. Only 37% of the variability of manganese concentration for the smallest and middle size fractions and 52% for the middle and largest size fractions was associated with particle size. Figure 5 presents the concentration ratios by metal and size fraction that were derived from the regression analysis. The figure also shows the median percent of the total sample mass for each of the size fractions.

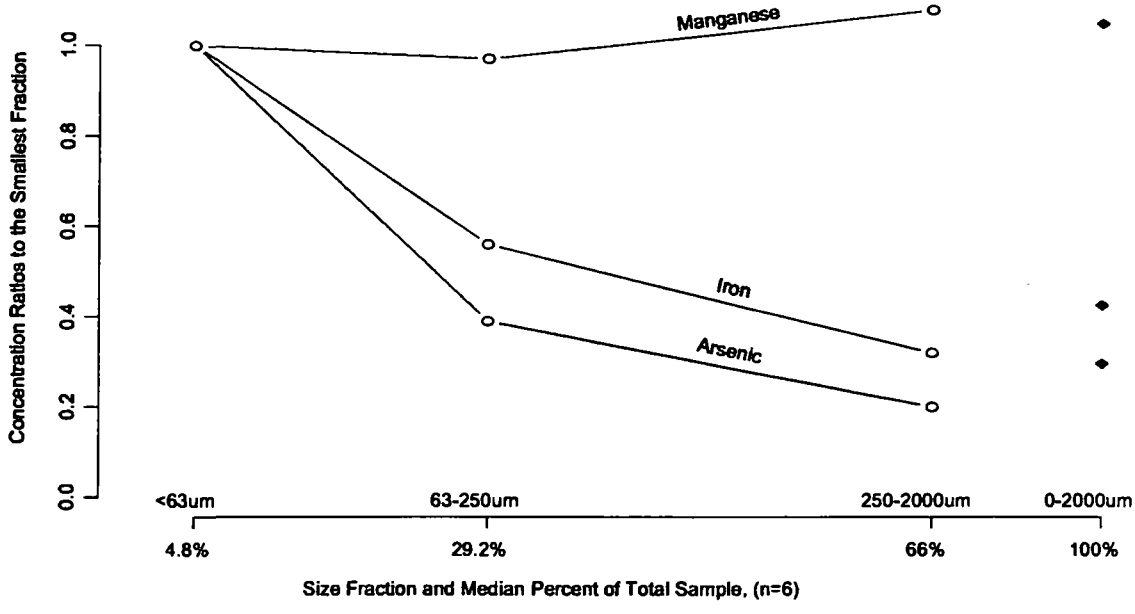


Figure 5. Metals concentrations relative to particle size and percent of total sample

The results of the regression analysis indicates that if a soil concentration of 10 mg/kg is assigned to the 0–63 µm size fraction of each metal, the concentrations associated with the other size fractions may be scaled according to the concentration ratios in Figure 5. These relative concentrations are shown in Table 7.

Table 7
Relative Concentrations (mg/kg) of Metals Among Particle Size Fractions

Analyte	0–63 µm	63–250 µm	0–2000 µm
Arsenic	10	3.9	3.0
Iron	10	5.6	4.3
Manganese	10	9.7	10.5

Risk is linearly related to exposure concentration for any exposure pathway. If the concentration doubles, the risk also doubles. Consequently, the relative risk associated with the use of size-fraction-specific concentration data for soil ingestion, dust inhalation, and dermal absorption pathways is simply based on the appropriate size fraction for each pathway (discussed above) and the relative concentrations for each metal by size fraction. For example, risks associated with inhalation of arsenic would be calculated to be three times higher using the pathway-specific 0–63 μm size fraction than the standard 0–2000 μm size fraction. The ratios of concentrations due to particle size presented in Figure 5 and Table 7 indicate that particle size is a worthwhile consideration during the planning for the Phase II field investigation.

The differences in the relative mass of each particle size fraction in the different geomorphic features (Figure 4) is likely to influence receptor exposure to contaminated sediments. As an example, the arsenic concentration for the 0–63 μm fraction is four times the concentration of the 250–2000 μm fraction, but the first fraction represents 4.6% of the total sample and the latter fraction represents 64% of the total sample. For the inhalation pathway, the relative amount of large, "nonerodible" particles can be used to modify the estimates of dust resuspension from the ground surface. For the soil ingestion and dermal exposure pathways, so long as there is sufficient quantity of fine (i.e., 0–250 μm) material available, it is likely that particle adherence on the skin will occur. What specifically constitutes a sufficient quantity is debatable as information relating soil adherence to the percentage of fines in a soil is lacking.

4.0 PRELIMINARY RISK ASSESSMENT

The results of the preliminary risk assessment are used to determine the potential significance of uncertainty in the measured soil concentrations and exposure models with respect to threshold risk criteria. If preliminary risk estimates are all far above or far below thresholds of concern, then understanding and reducing sources of uncertainty is unlikely to change decisions. If the preliminary risk assessment results are close to thresholds of concern then further analysis to reduce uncertainty may change the basis of decisions.

The preliminary risk assessment was performed using RME parameter values in accordance with EPA guidance (EPA, 1989) and with metal concentrations in the 0–250 μm size fraction. Different estimates of the central tendency of metals concentrations in overbanks, bars, and the active channel across E1 are shown in Table 5 including the logarithmic mean, the 95 percent upper confidence limit on the median (95UCL on the median), and the 95 percent upper confidence limit on the logarithmic mean (95UCL on the log mean). These three values represent the uncertainty in the average concentrations of key metals across E1. However, recall that the variability in metals concentrations among geomorphic features, as shown in Figures 1–3 indicates that metals data should not be treated as a single statistical population and that metals concentrations in unsampled geomorphic features may be poorly predicted from the existing data. Metal concentrations in smaller areas within E1 may either exceed or be lower than the average values used in this assessment. The preliminary risk assessment is meant to be used as a "broad brush" to identify the approximate magnitude of risk values within E1.

The preliminary risk assessment uses the 95UCL on the log mean for the hazard and risk calculations. As shown in Table 5, metal concentrations among the logarithmic mean, the 95UCL on the median, and the 95UCL on the log mean are generally within about 25% of each other. However, the maximum metal concentrations in Table 5 are often two to three times larger than these measures of the average, even though these measures are biased towards being a protective estimate of concentrations across E1. This suggests that small-scale variability in metal concentrations may be greater than uncertainty in estimates of large-scale average concentrations.

The results of the preliminary risk assessment are shown in Table 8. The on-site residential exposure scenario is limited to overbanks because permanent residences cannot be established on the bars and in the active channel where seasonal flooding is the norm. The off-site residential scenario evaluates the consequences of using soils excavated from the active channel and bars for grading and resurfacing a residential lot at a remote location. The recreational and resource use scenario addresses activities such as walking and playing, as well as use of the IU for grazing cattle and for collecting wild plants. These scenarios, and the associated geomorphic features and exposure pathways, are described in the Conceptual Site Model presented earlier in this memorandum.

Table 8
Results of the Preliminary Risk Assessment for Exposure Reach 1

Geomorphic Feature	Child HI	Adult HI	ICR
On-Site Residential Land Use			
Overbank	21	19	3E-04
Off-Site Residential Land Use			
Bars	5	2	2E-05
Active channel	4	2	2E-05
Recreational/Resource Use			
Overbank	3	2	1E-05
Bars	3	2	2E-05
Active channel	3	2	2E-05

The results of the preliminary risk assessment indicate that chemical hazards are generally greater than a hazard index of one, which is the threshold value for possibly observing adverse health effects in the receptor population. However, the hazards across all key metals were summed without attention to what organ each metal affects. Therefore, it is likely that RME HI values calculated in a baseline risk assessment will be lower than indicated in Table 8.

The incremental cancer risk (ICR) value for the on-site residential scenario was above EPA's target risk range of 10^{-4} to 10^{-6} described in the National Contingency Plan (EPA, 1990). However, the majority of the on-site residential risk is associated with ingestion of home-raised chicken and eggs. As discussed in Section 5, the feed-to-tissue transfer factors applied in the calculations are highly uncertain and may be biased towards high values. For the off-site residential and recreation/resource use scenarios, which do not include the ingestion of chickens and eggs grown on sediments from the IU, calculated risks were within the target risk range. Therefore, the ICR results of the preliminary risk assessment suggest that RME cancer risks calculated in the baseline risk assessment may lie within or just above the risk range for remedial decision making.

The risk assessment equations and exposure parameter values for the exposure pathways associated with the exposure scenarios described in Table 8 are provided in Attachment 1.

5.0 UNCERTAINTY AND SENSITIVITY ANALYSIS

Evaluating the uncertainty and sensitivity of a risk estimate provides two indications of how to improve that estimate. The uncertainty analysis determines how the calculated risk changes when the inputs to the

risk equations are varied to reflect uncertainty in these values. The sensitivity analysis identifies which specific exposure variables make the most difference in the estimated risk. The combination of uncertainty and sensitivity analysis identifies where to focus the gathering of additional information in order to improve confidence in the risk estimates.

The uncertainty and sensitivity analyses were performed for on-site residential use of overbanks. This land use scenario results in the highest HI and ICR estimates in the preliminary risk assessment (Table 8). The results of the sensitivity and uncertainty analyses for the on-site residential scenario can also be applied to off-site residential use of EI bar and channel sediments by removing the pathways related to home-raised chickens.

Uncertainty Analysis

The difference in risk estimates resulting from CTE and RME assumptions is a simple method of assessing the effect of uncertainty in the exposure variables. The RME and CTE values for the inputs to the on-site residential scenario equation are shown in Table 9. A complete tabulation of exposure parameter values, and the risk equations in which they are used, is provided for all exposure scenarios in Attachment 1. RME and CTE values for soil-chicken and soil-egg uptake factors are not included in Table 9 because adequate information to differentiate reasonable maximum and central tendency values for these parameters was not found in the literature. Because this analysis is limited to exposure variables, uncertainty associated with EPA-recommended toxicity values for carcinogenic and noncarcinogenic effects is not addressed.

The results of the uncertainty analysis calculations are shown in Table 10. There are differences between the RME results shown in Table 10 and the results of the preliminary risk assessment calculations shown in Table 8 because different sources of information for the plant-soil concentration ratios were used in the preliminary risk assessment and uncertainty analysis. The preliminary risk assessment calculations were performed with plant-soil concentration ratios for the reproductive portions of plants obtained from *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture* (Baes et al., 1984). This publication is widely used in both chemical and radiological risk assessments as a reference for plant-soil concentration ratios and reproductive parts of a plant (fruits and seeds) are more commonly associated with garden vegetables. For the uncertainty analysis, a more recent publication (*Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants*, Bechtel Jacobs Company, 1998) was employed as a reference because this publication provides information useful for assessing the uncertainty in metal-specific values of plant-soil concentration ratios. However, the Bechtel publication provides plant-soil concentration ratios based primarily on the vegetative rather than the reproductive portions of a plant. Concentrations of arsenic, copper, iron, manganese and zinc in the vegetative portion of a plant may exceed those in reproductive parts of the plant by factor ranging between approximately 2 and 10 (Baes et al., 1984). Hence, RME cancer risk and hazard quotient values in Table 10 are somewhat elevated relative to those presented in Table 8.

The RME value for cancer risk is 1E-03, which is a factor of ten greater than the upper end of EPA's target risk range of 10^{-4} to 10^{-6}. The CTE value is closer to the midpoint of the target risk range. The difference between the RME and CTE estimates is approximately a factor of 30. Because the RME and CTE values lie outside and within the target risk range, respectively, there is a high value in identifying the main inputs contributing to this difference and determining whether uncertainty in the cancer risk estimate may be reduced. Note that this analysis, like the preliminary risk assessment, uses an estimate of the average concentration of arsenic across all of E1. Arsenic concentrations within E1 are highly variable and smaller areas within E1 where exposure may occur may have arsenic concentrations that are higher or lower than that used in these calculations.

Table 9
RME and CTE Values Used in the Uncertainty Analysis

Parameter	RME Value	CTE Value
On-Site Residential Exposure (Exposure Reach 1)		
Soil exposure concentration[a] (mg/kg)	As (9.39); Cu (1,610); Fe (31,900); Mn (1,350); Zn (1,960)	As (3.82); Cu (938); Fe (23,600); Mn (1,000); Zn (865)
Plant-soil concentration ratio[b]	As (1.103); Cu (0.625); Fe (0.01); Mn (0.234); Zn (1.82)	As (0.0375); Cu (0.124); Fe (0.00425); Mn (0.0792); Zn (0.366)
Child on-site soil ingestion rate	136.5 mg/day	40.5 mg/day
Adult on-site soil ingestion rate	50 mg/day	26.5 mg/day
Adult exposure duration (cancer effects)	24 yr	3 yr
Adult exposure duration (noncancer effects)	30 yr	9 yr
Child inhalation rate	0.42 m3/hr	0.33 m3/hr
Child daily exposure time	22.4 hr/day	21.1 hr/day
Adult daily exposure time	19 hr/day	17.5 hr/day
Child skin surface area	2800 cm^2	2800 cm^2
Adult skin surface area	5700 cm^2	5700 cm^2
Child soil adherence factor	0.2 mg/cm^2-day	0.04 mg/cm^2-day
Adult soil adherence factor	0.07 mg/cm^2-day	0.01 mg/cm^2-day
Vegetable ingestion rate	1.2 g/kg-day	0.4 g/kg-day
Fruit ingestion rate	1.4 g/kg-day	0.53 g/kg-day
Chicken ingestion rate	1.3 g/kg-day	0.7 g/kg-day
Egg ingestion rate	1.05 g/kg-day	0.67 g/kg-day

[a] RME value is the 95UCL on the log mean for E1 overbanks; CTE value is the median (see Table 5). Exposure concentration values are based on the 0–250 µm particle size fraction.

[b] From a database presented in Bechtel (1998). RME value is the 90th percentile; CTE value is the median – Tables 6 and D-1 of Bechtel (1998).

Table 10
Results of the Uncertainty Analysis for the On-Site Residential Scenario in Exposure Reach 1

Analyte	Child Hazard Quotient	Adult Hazard Quotient	Cancer Risk
Reasonable Maximum Exposure Assumptions			
Arsenic	6.3	6.0	1E-03
Copper	4.8	4.5	
Iron	12	11	
Manganese	2.2	1.3	
Zinc	3.7	3.6	
Hazard Index	**28**	**26**	
Central Tendency Exposure Assumptions			
Arsenic	0.48	0.45	3E-05
Copper	0.66	0.61	
Iron	4.7	4.6	
Manganese	0.72	0.34	
Zinc	0.590	0.59	
Hazard Index	**7.2**	**6.6**	

The result of the uncertainty analysis for chemical hazard is similar to that for cancer risk. Hazard quotients for individual chemicals in the RME calculation exceed the threshold of one for all metals and for both adult and child receptors. With the exception of iron, HQ values for the CTE calculations lie below the threshold of one. The HI values shown in Table 10 are likely to be unrealistically high, since the toxic effects associated with the reference dose values of the individual metals are not all additive. However, some metals present in the H/WC IU may have effects on similar organ systems (for example, lead and manganese both affect the central nervous system). In other cases, co-located metals may have an antagonistic effect on toxicity (for example, ingestion of zinc inhibits the uptake of copper in the gastrointestinal tract). Although this subject is beyond the scope of this memorandum, these examples are mentioned to draw attention to the fact that even though the HQ values are not additive, the presence of several metals at potentially toxic concentrations presents another aspect of uncertainty that is not captured in the EPA-recommended toxicity values used in these calculations nor in the RME and CTE framework.

EPA does not publish toxicity values for lead, hence lead has not been addressed in these calculations and does not appear in Table 10. EPA has recently published a final rule under Section 403 of the Toxic Substances Control Act regarding soil lead concentrations in certain housing and child-occupied facilities (FR Vol. 66, No.4, January 5, 2001). This rule specifies a maximum soil lead concentration of 400 mg/kg for children's play areas and 1,200 mg/kg as an average concentration in the remainder of a residential yard. This new rule is consistent with earlier guidance for RCRA and CERCLA sites (*Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities*, EPA, 1994), which specifies a residential screening value for lead of 400 mg/kg. The 95UCL log mean for lead in overbank soils is 376 mg/kg, with a maximum value of 657 mg/kg. These data suggest that lead concentrations may be of concern in some overbanks where a residential scenario is applicable.

Sensitivity Analysis

The results of the uncertainty analysis indicate that there is value in reducing the uncertainty in both cancer risk and chemical hazard estimates for E1 overbanks. In the sensitivity analysis, the results of the uncertainty analysis are explored in more depth to identify the input parameters to the RME and CTE calculations that are responsible for the differences between them.

The relative contribution of the five metals to the hazard index (the sum of the hazard quotients for the individual metals) is shown graphically in Figure 6. The primary difference between the HI for RME and CTE estimates is in the relative importance of iron. In both the RME and CTE calculation, iron is the primary contributor to chemical hazard, although it is more dominant in the CTE calculation. Arsenic is the only metal evaluated for which EPA publishes a cancer toxicity value, hence it contributes 100% to the RME and CTE cancer risks. Arsenic makes a contribution to both the HI and ICR values because both systemic and carcinogenic effects are associated with exposure to this element.

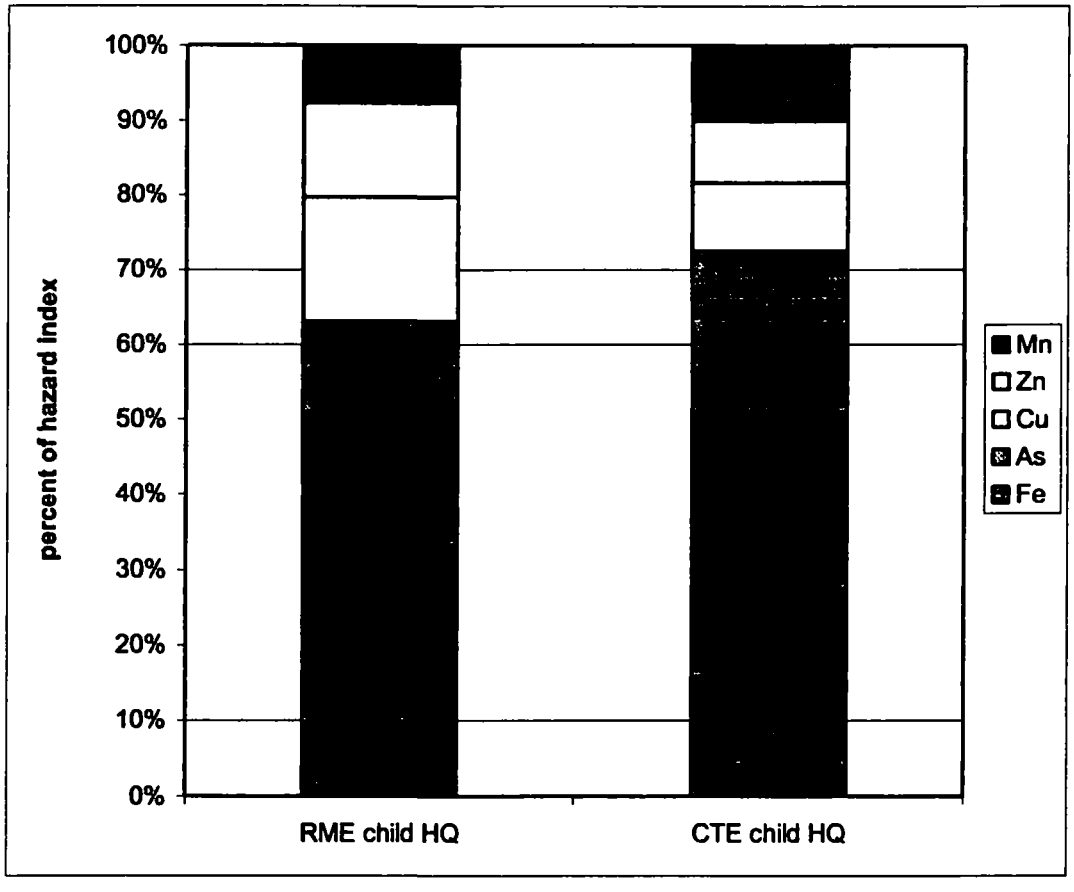


Figure 6. Relative contribution of individual metals to RME and CTE hazard index

The relative contribution of the various exposure pathways associated with the on-site residential scenario, and of each individual metal within each pathway, is shown in Table 11. Each cell in the table contains the percent contribution of the metal/pathway combination to the HQ or ICR value shown in Table 10. The exception to this are the two rows with values in bold font; these cells show the percent

contribution of the exposure pathway across all five metals to the HI values shown in Table 10. Because child and adult hazards are similar, only child HQ is shown in Table 11.

Table 11
Fractional Contribution of Exposure Pathways and Metals
to RME and CTE Chemical Hazards and Cancer Risks in the Uncertainty Analysis

	Soil Ingestion	Dust Inhalation	Soil Dermal	Plant Ingestion	Chicken Ingestion	Egg Ingestion
ICR RME Pathway Analysis						
Arsenic	1.05	0.024	0.16	69.1	16.7	13.0
Child HQ and HI RME Pathway Analysis						
Arsenic	3.8	NA*	0.46	67.0	16.2	12.6
Copper	6.3	0.080	0.00	63.9	16.7	13.0
Iron	6.95	NA	0.00	1.12	54.1	37.9
Manganese	10.0	46.7	0.00	37.9	2.60	2.73
Zinc	1.33	NA	0.00	39.2	44.9	14.5
All 5 Metals	**5.65**	**3.56**	**0.10**	**34.0**	**34.3**	**22.4**
ICR CTE Pathway Analysis						
Arsenic	4.35	0.167	0.36	4.26	47.3	43.6
Child HQ and HI CTE Pathway Analysis						
Arsenic	5.95	NA	0.49	4.19	46.5	42.9
Copper	7.95	0.250	0.00	18.5	38.2	35.1
Iron	3.72	NA	0.00	0.297	52.5	43.5
Manganese	6.59	76.64	0.00	9.81	3.10	3.86
Zinc	1.08	NA	0.00	7.44	66.2	25.3
All 5 Metals	**4.32**	**7.72**	**0.033**	**3.78**	**46.9**	**37.2**

*NA = Not available. No inhalation toxicity value is available to evaluate this exposure pathway.

The pathway component of the information shown in Table 11 is shown graphically for HQ and ICR in Figures 7 and 8, respectively.

There are two conclusions that may be drawn from the information shown in Table 11, and in Figures 7 and 8. The first conclusion is that the chicken and egg ingestion exposure pathways are a dominant factor in the cancer risk and hazard quotient for the on-site residential exposure scenario. These two pathways are responsible for 84% of the CTE hazard index and 91% of the CTE cancer risk, and about 57% of the RME hazard index. As noted above, there is inadequate information available to develop RME and CTE estimates of chemical-specific soil-chicken and soil-egg uptake factors. However, the effect of this pathway on the magnitude of cancer risk and chemical hazard results indicates that accuracy in estimating actual tissue concentrations of metals is of great importance. Because the differences between RME and CTE estimates of the amount of home-raised chicken and egg eaten are less than a factor of two, the soil-chicken and soil-egg uptake factors are the only exposure variables related to these exposure pathways where additional information might substantially improve confidence in the risk and hazard results.

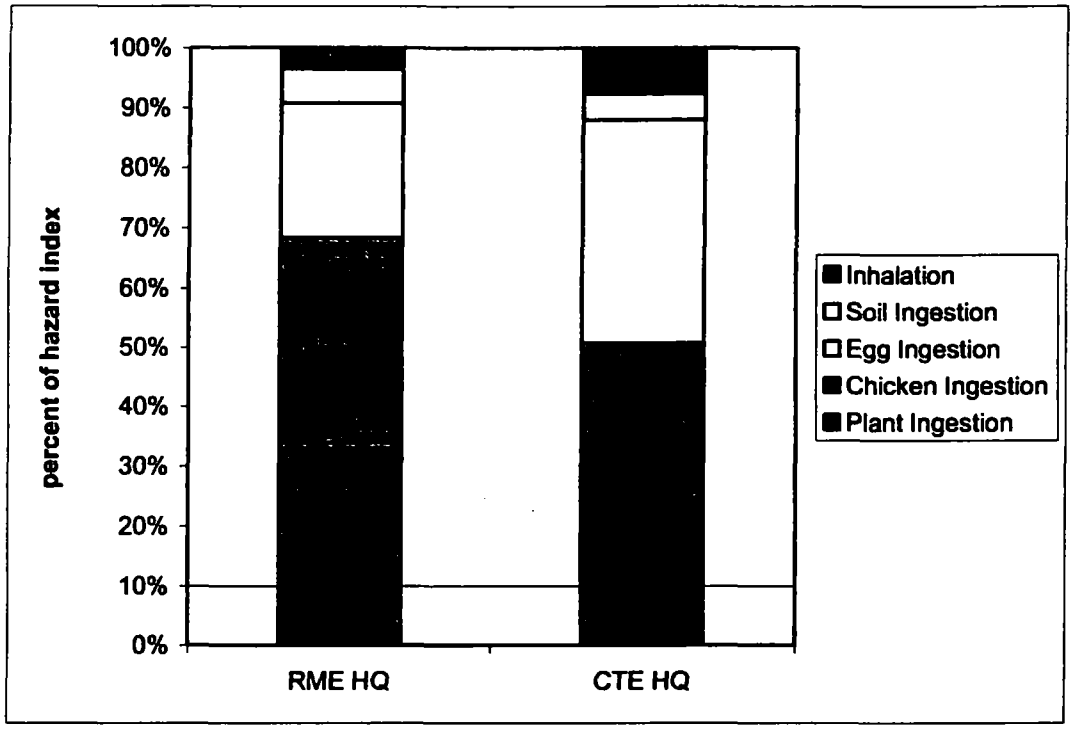


Figure 7. Relative contribution of exposure pathways to RME and CTE hazard index

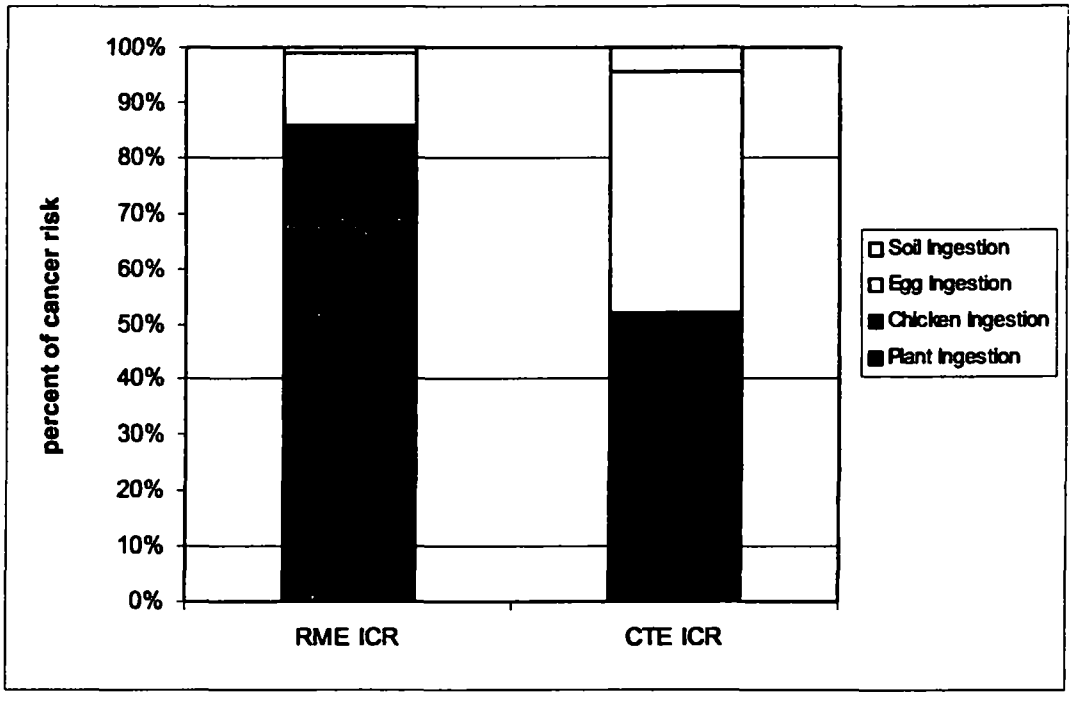


Figure 8. Relative contribution of exposure pathways to RME and CTE cancer risk

The second conclusion is that the relative importance of the plant ingestion exposure pathway increases using RME exposure assumptions, particularly for the cancer risk calculations. In the RME cancer risk calculation, plant ingestion is responsible for 69% of the total cancer risk across all exposure pathways. A review of the RME and CTE information in Table 9 indicates that the plant-soil ratio for arsenic is the main reason for the increasing importance of plant ingestion in the RME calculation. The difference between the RME and CTE values of the arsenic plant-soil concentration ratio is approximately a factor of 30. By contrast, the differences between RME and CTE values for soil exposure concentrations and plant ingestion rates are only about a factor of three or less.

Potential Influence of Background Metal Concentrations

Exposure variables other than plant-soil concentration ratios and soil-chicken and soil-egg uptake factors may also be significant sources of uncertainty. However, their significance is difficult to assess because it is dependent on first reducing uncertainty in the plant-soil concentration ratios and soil-chicken or -egg uptake factors, which together dominate the magnitude and range of CTE and RME estimates of chemical hazard and cancer risk. However, there is one aspect of uncertainty with respect to soil exposure concentrations that warrants particular attention. This is the contribution of ambient (background) metal concentrations to total measured concentrations of metals in the H/WC IU.

The contribution of background levels of metals to the measured metal concentrations in Phase I sediment data may be important for informing risk-based remedial decisions. For example, consider the consequences if background levels of arsenic were to contribute 50%, or 5%, of a calculated cancer risk of 10^{-4}. The incremental cancer risk in the former case would be 5×10^{-5} above a background risk of 5×10^{-5}. For the case where background levels of arsenic contribute only 5% of total risk, the incremental cancer risk would be 9.5×10^{-5} above a background risk of 5×10^{-6}. These two cases could result in very different risk management decisions.

Background concentrations of metals may also affect interpretation of the results of uncertainty and sensitivity analyses. Recall that the arsenic plant-soil concentration ratio was a particularly sensitive parameter in creating the range between CTE and RME estimates of chemical hazard and cancer risk. In the example introduced in the previous paragraph, the relative importance of reducing uncertainty in the arsenic plant-soil concentration ratio might be quite different depending on whether arsenic background concentrations were 5% or 50% of site concentrations.

Two sources of existing information relating to possible background concentrations of metals in the area of the H/WC IU are the *Background Report, Chino Mine Investigation Area* (CMC, 1995) and the report *Waste Rock Characterization, Chino Mine* (GAI, 1998). The background data presented in the Background Report likely represent both mineralized and unmineralized areas of the stream system (personal communication, Kent Johnejack, GAI) and were not collected under any specific guidelines for use as background data for the H/WC IU risk assessment. Data described in the Waste Rock Characterization report provide the composition of rocks. These data can be very different from the sediments and soils in the H/WC stream system. Although the data in these reports are not directly applicable to establishing background metal concentrations in the H/WC IU, they may provide an approximate indicator of where background concentrations may lie. This is useful in determining the potential importance of establishing background metals concentrations in the H/WC IU.

A summary of the data from the Background Report and the Waste Rock Characterization report for the six metals evaluated in this memorandum is presented in Tables 12 and 13.

Table 12
Background Report "Reference Levels" for Key Metals

Metal	Minimum (mg/kg)	Maximum (mg/kg)
Arsenic	1.4	5.4
Copper	53	280
Iron	4,200	30,000
Lead	18	190
Manganese	330	1,100
Zinc	50	440

Note: Data rounded to two significant figures.

Table 13
Waste Rock Report Average Concentrations for Key Metals

Metal	Beartooth/Colorado Formation (mg/kg)	Dikes and Whim Hill Breccia (mg/kg)	Sugarlump and Kneeling Nun Tuff (mg/kg)	Granodiorite (mg/kg)
Arsenic	1	2	1	1
Copper	750	1,800	40	2,100
Iron	NA*	NA	NA	NA
Lead	5	24	20	10
Manganese	NA	NA	NA	NA
Zinc	23	170	50	50

Note: Data rounded to two significant figures.
*NA = Not available.

With the possible exception of manganese, concentrations of these metals in Exposure Reach 1 (see Table 5) are generally greater than the values shown in Tables 12 and 13. The range between minimum and maximum stream reference area metal values is relatively large, and the metal concentrations in parent rock types are generally low compared to the stream values. Establishing background concentrations at different points within the range of values shown in Tables 12 and 13 could substantially impact the results of uncertainty and sensitivity analyses. Determining background metal concentrations for sediments and soils in the H/WC basin is therefore critical for applying the results of the risk assessment calculations to risk-based decisions. In the absence of background data, it is commonly assumed in the practice of risk assessment that measured contaminant concentrations at a site are wholly related to site activities.

6.0 CONCLUSIONS AND RECOMMENDATIONS

Among the 21 metals in the H/WC characterization data set, six metals were identified in the screening risk assessment (Section 2) as being of particular relevance to potential human health impacts in the H/WC IU. These metals are arsenic, copper, iron, lead, manganese, and zinc. Sediment data for these metals in Exposure Reach 1, the region of the IU where metal concentrations exceeded screening levels

by the greatest margins, were evaluated to determine variability in metals concentrations with particle size, sample depth, geomorphic feature, and location with Exposure Reach 1. Following this evaluation, estimates of the average metal concentrations within Exposure Reach 1 were generated.

Reasonable maximum exposure estimates of metal concentrations and potential exposure intensity in Exposure Reach 1 were used in a preliminary risk assessment to determine the approximate magnitude of chemical hazard and cancer risk. Chemical hazard and cancer risk values exceeded threshold criteria. Subsequent uncertainty and sensitivity analysis revealed that risk estimates using CTE estimates of metal concentrations and potential exposure intensity were close to threshold criteria. Differences between CTE and RME estimates of chemical hazard and cancer risk were found to be most sensitive to uncertainty in the values of plant-soil concentration ratios, soil-chicken uptake factors, and soil-egg uptake factors. The relative contribution of background levels of metals to concentrations within the H/WC IU was also determined to be of great importance for determining mining-related contributions to total risk in the IU.

The following data needs are identified for Phase II of the H/WC remedial investigation:

1. metal concentrations in fruits and vegetables grown in H/WC IU soils with metal concentrations in the range identified in this memorandum;
2. metal concentrations in chicken meat and eggs from chickens raised on H/WC IU soils with metal concentrations in the range identified in this memorandum, and;
3. background concentrations of metals representative of geomorphic features across the length of the H/WC IU.

Metal concentrations in plants, chicken tissue, and eggs were modeled using plant-soil concentration ratios, soil-chicken uptake factors, and soil-egg uptake factors in the calculations performed for the preliminary risk assessment and uncertainty/sensitivity analysis. As indicated in Table 9, values for plant-soil concentration ratios may vary widely. This is expected because factors such as soil type, metal concentrations in soil, and plant characteristics will all affect the relative amount of a specific chemical taken up by a plant via its roots. For this reason, the optimum measure of plant tissue metal concentrations in a site-specific risk assessment is sample data from garden produce grown in site soils. A similar logic pertains to information for chicken and egg metal concentrations. Because metal concentrations vary across the IU, and because gardens and chicken enclosures commonly occupy a small area, data for plant, chicken and egg metal concentrations must be generated in such a manner that the correlation of metal concentrations in soil and foodstuffs is clearly defined. For these reasons, site-specific studies to generate information on metal concentrations in garden produce, chicken meat, and eggs are recommended.

Estimates of chemical hazard and cancer risk within the H/WC IU can be made without knowledge of background metal concentrations. However, risk-based remedial decisions made without background information will likely result in mitigations for larger areas. Being able to separate mining-related metals concentrations from background concentrations allows the "footprint" of mining-related contamination to be defined and provides lower bounds for any calculated risk-based remedial action criteria. Therefore, it is recommended that a study be conducted to establish background metal concentrations within the H/WC IU.

GAI, 1999. *Administrative Order on Consent, Phase I Remedial Investigation Report, Hanover and Whitewater Creeks Investigation Units*. Prepared by Golder Associates, Incorporated, for Chino Mines Company, Hurley, New Mexico. December 17, 1999.

GAI, 1998. *Waste Rock Characterization, Chino Mine*. Prepared by Golder Associates, Incorporated, for Chino Mines Company, Hurley, New Mexico. August, 10, 1998.

Helsel and Hirsh, 1992. *Studies in Environmental Science 49, Statistical Methods in Water Resources*, Elsevier Science B.V., Amsterdam, The Netherlands.

Kissel et al., 1996. Factors Affecting Soil Adherence to Skin in Hand-Press Trials. *Bulletin of Environmental Contamination and Toxicology*, 56:722-728.

N&C, 1999. *Administrative Order on Consent, Human Health Risk Assessment Work Plan, Hanover/Whitewater Creek Investigation Unit*. Prepared for the New Mexico Environment Department, Santa Fe, New Mexico. June 1999.

7.0 REFERENCES

Baes et al., 1984. *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture.* Prepared for the U.S. Department of Energy. Health and Safety Research Division, Oak Ridge National Laboratory, Tennessee. September 1984.

Bechtel, 1998. *Empirical Models for the Uptake of Inorganic Chemicals by Plants.* BJC/OR-133. Prepared for the U.S. Department of Energy, Office of Environmental Management by Bechtel Jacobs Company LLC. September 1998.

CMC, 1995. *Administrative Order on Consent, Investigation Area, Remedial Investigation, Background Report, Chino Mine Investigation Area.* Prepared for New Mexico Environment Department by the Chino Mines Company. October 5.

DBS and GAI, 1998. Daniel B. Stephens & Associates and Golder Associates. *Administrative Order on Consent, Phase I Remedial Investigation Proposal, Hanover and Whitewater Creeks Investigation Unit.* Prepared for Chino Mines Company, Hurley, New Mexico. August 28, 1998.

Duggan and Inskip, 1985. Childhood Exposure to Lead in Surface Dust and Soil: A Community Health Problem. *Public Health Rev.* 1985; 13:1-54.

EPA, 2001a. *Risk Assessment Guidance for Superfund: Volume III – Part A, Process for Conducting Probabilistic Risk Assessment.* EPA 540-R-02-002, OSWER Directive 9285.7-45, Washington, D.C.: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. December 2001.

EPA, 2001b. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment, Interim.* EPA 540-R-99-005, OSWER Directive 9285.7-02EP, Washington, D.C.: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response. September 2001.

EPA, 1997. *Exposure Factors Handbook, Volume I, General Factors*, EPA/600/P-95/002Fa. Washington, D.C.: U.S. Environmental Protection Agency, Office of Research and Development. August.

EPA, 1994. *Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities*, OSWER Directive 9355.4-12, Memorandum from Elloitt P. Laws, Assistant Administrator, to Regional Administrators I- X, Washington, D.C.: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. July 1994.

EPA, 1992. *Guidance on Risk Characterization for Risk Managers and Risk Assessors.* Memorandum from F. Henry Habicht II, Deputy Administrator, to Assistant and Regional Administrators, Washington, D.C.: U.S. Environmental Protection Agency. February 1992.

EPA, 1990. National Oil and Hazardous Substances Pollution Contingency Plan. Final Rule, 40CFR300: 55 *Federal Register*, 8666-8865, Washington, D.C.

EPA, 1989. *Risk Assessment Guidance for Superfund (RAGS), Volume I, Human Health Evaluation Manual (Part A), Interim Final*, OSWER Directive 9285.7-01A. Washington, D.C.: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response.

GAI, 2000. *Phase I Remedial Investigation Report (Revised), Hanover and Whitewater Creeks Investigation Units.* Prepared by Golder Associates, Incorporated, for Chino Mines Company, Hurley, New Mexico. May, 25, 2000.

ATTACHMENT 1

Supporting Information for
Risk Assessment Calculations and Results

EQUATIONS FOR CALCULATION OF HAZARD QUOTIENT AND CANCER RISK

Exposure pathways evaluated for reasonable maximum and central tendency exposure are identified in the following table for Exposure Area 1 (E1), Exposure Area 2 (E2), and Exposure Area 3 (E3).

Exposure Pathway	E1 / E3 On-Site Residential	E1 Off-Site Residential	E1 Recreation / Resource Use	E2 Trespasser and E3 Recreational
Soil Ingestion	X	X	X	X
Dust Inhalation	X	X	X	X
Dermal Absorption from Soil	X	X	X	X
Ingestion of Garden Produce and Fruit	X	X		
Ingestion of Wild Plant Products			X	
Meat Ingestion			X	
Chicken Ingestion	X			
Egg Ingestion	X			

Pathway-specific hazard and risk from the following equations are summed across pathways to calculate hazard or risk for each metal and exposure scenario. Values and references for each exposure parameter under RME and CTE conditions, specific to each exposure scenario, are provided in two accompanying tables. Note that the subscripts "a" and "c" are used to distinguish adult and child parameters, respectively, for the parameters in the accompanying tables. Chemical-specific parameter values pertaining to the food ingestion pathways, and chemical-specific values pertaining to dermal absorption, gastrointestinal absorption, and toxicity, are provided in three additional tables.

Equations are described for the "forward" calculation of chemical hazard and cancer risk. Equations for the calculation of RBSL values for each pathway can be developed from those provided by manipulating the equations to solve for the constituent concentration in soil. Target hazard quotient and cancer risk values used in the calculation of RBSL values are one and 10^{-6}, respectively. To calculate RBSL values across multiple exposure pathways, the inverse of the sum of the reciprocals is used. For example, for a scenario with three exposure pathways (shown as RBSL 1 through 3), the following equation would apply:

$$RBSL_{scenario} = \frac{1}{1/RBSL_1 + 1/RBSL_2 + 1/RBSL_3}$$

Chemical Hazard

HQ is a hazard quotient, defined as the ratio of the exposure level to a single chemical (i) to the toxicity reference dose for that chemical. Individual hazard quotients may be summed to obtain a hazard index for all, or some, chemicals. For soil ingestion, dust inhalation, and dermal absorption, separate adult and child HQs are calculated. For ingestion of food products, a single hazard quotient is calculated because the ingestion rate data used in the calculations integrates exposure across a population of both children and adults.

Soil Ingestion

$$HQ = (C_{s,i} \times IR_{s,site} \times EF \times ED_{nc} \times 10^{-6}\ kg/mg) / (BW \times AT_{nc} \times RfD_{ing,i})$$

Where
- $C_{s,i}$ = concentration of contaminant i in exposure area soil (mg/kg soil)
- $IR_{s,site}$ = site-specific soil ingestion rate (mg of soil/day)
- EF = exposure frequency (day/yr)
- ED_{nc} = exposure duration, noncarcinogenic effects (year)
- BW = body weight (kg)
- AT_{nc} = averaging time, noncarcinogenic effects (day)
- $RfD_{ing,i}$ = ingestion reference dose, contaminant i (mg/kg-d)

The site-specific soil ingestion rate ($IR_{s,site}$) is calculated according to the following equation, where the term within square brackets is constrained to be one or less;

$$IR_{s,site} = IR_s \times [(E_{out} \times T_{site,out} + T_{site,in} / E_{out}) / (E_{out} \times T_{out} + (T_{in} - T_{sleep}) / E_{out})]$$

Where
- IR_s = daily soil ingestion rate (mg of soil/day)
- E_{out} = outdoor activity soil loading enrichment factor (unitless)
- $T_{site,out}$ = time on-site spent outdoors (hour/day)
- $T_{site,in}$ = time on-site spent indoors (hour/day)
- T_{out} = total time spent in an outdoor environment (hour/day)
- T_{in} = total time spent in an indoor environment (hour/day)
- T_{sleep} = time spent sleeping or napping (hour/day)

Dust Inhalation

$$HQ = (C_{s,i} \times EF \times InhR \times ET \times ED_{nc}) / (PEF \times BW \times AT_{nc} \times RfD_{inh,i})$$

Where
- $C_{s,i}$ = concentration of contaminant i in source area soil (mg/kg soil)
- InhR = inhalation rate (m^3/hour)
- ET = exposure time (hour/day)
- EF = exposure frequency (day/year)
- ED_{nc} = exposure duration, noncarcinogenic effects (year)
- PEF = particulate emission factor (m^3/kg)
- BW = body weight (kg)
- AT_{nc} = averaging time, noncarcinogenic effects (day)
- $RfD_{inh,i}$ = inhalation reference dose, contaminant i (mg/kg-d)

and $PEF = (Q/C \times 3600 \text{ sec/hr}) / (0.036 \times (1-v) \times (U_m / U_{t-7})^3 \times F(x))$

and $U_{t-7} = (U_t / 0.4) \times \ln(z / z_0)$

where
- Q/C = inverse of mean concentration at the center of a square source area (g/m^2-sec per kg/m^3)
- v = fraction of vegetative cover (dimensionless)
- U_m = mean annual windspeed (m/sec)
- $F(x)$ = function dependent on U_m / U_{t-7} (dimensionless)
- U_{t-7} = equivalent threshold value of windspeed at 7 m (m/sec)
- U_t = threshold friction velocity at height z above surface (m/sec)
- z = height above surface (m)
- z_0 = surface roughness height (m)

Dermal Absorption from Soil

$$HQ = (C_{s,i} \times ABS_i \times SA \times AF \times EF_{derm} \times ED_{nc} \times 10^{-6} \text{ kg/mg}) / (BW \times AT_{nc} \times RfD_{ing,i} \times F_{oral,i})$$

Where
- $C_{s,i}$ = concentration of contaminant i in exposure area soil (mg/kg soil)
- ABS_i = dermal absorption factor, contaminant i (unitless)
- SA = exposed skin surface area (cm^2)
- AF = soil adherence factor (mg/cm^2–event)
- EF_{derm} = exposure frequency for dermal contact with soil (event/yr)
- ED_{nc} = exposure duration, noncarcinogenic effects (year)
- BW = body weight (kg)
- AT_{nc} = averaging time, noncarcinogenic effects (day)
- $RfD_{ing,i}$ = ingestion reference dose, contaminant i (mg/kg-d)
- $F_{oral,i}$ = oral absorption factor, contaminant i (unitless)

Ingestion of Garden Produce or Wild Plant Products

$$HQ = [C_{s,i} \times K_{p\text{-}s,i} \times ((IR_v \times depth_{cz} / depth\_root_v) + (IR_f \times depth_{cz} / depth\_root_f)) \times EF_{food} \times ED_{nc} \times 0.001 \text{ kg/g}] / (AT_{nc} \times RfD_{ing,i})$$

Where
- $C_{s,i}$ = concentration of contaminant i in garden, orchard, or plant collection area soil (mg/kg soil)
- $K_{p\text{-}s,i}$ = plant:soil concentration ratio, contaminant i (mg/kg wet plant per mg/kg soil)
- IR_v = ingestion rate of home-grown vegetables; wet weight (g/kg-day)
- IR_f = ingestion rate of home-grown fruits; wet weight (g/kg-day)
- $depth_{cz}$ = depth of contaminated zone (cm)
- $depth\_root_v$ = effective rooting depth of garden vegetables; <= to $depth_{cz}$ (cm)
- $depth\_root_f$ = effective rooting depth of fruit trees; <= to $depth_{cz}$ (cm)

EF_{food} = exposure frequency for ingesting food products (day/year)
ED_{nc} = exposure duration, noncarcinogenic effects (year)
AT_{nc} = averaging time, noncarcinogenic effects (day)
$RfD_{ing,i}$ = ingestion reference dose, contaminant i (mg/kg-d)

Note: The ratio $depth_{cz}$: depth_root is used for garden soils to account for the percentage of soil amendment or fill mixed with local (contaminated) soil. The value of this ratio is constrained to be one or less.

Beef Ingestion

$$HQ = [C_{s,i} \times TF_{s\text{-}b,i} \times ((UR_g \times K_{g\text{-}s,i}) + UR_s) \times IR_m \times F_r \times EF_{food} \times ED_{nc} \times 0.001\ kg/g] / (AT_{nc} \times RfD_{ing,i})$$

Where
$C_{s,i}$ = concentration of contaminant i in range area soil (mg/kg soil)
$TF_{s\text{-}b,i}$ = soil-beef transfer factor, contaminant i (mg/kg beef per mg/day)
UR_g = uptake rate of grass by cattle, wet weight (kg/day)
$K_{g\text{-}s,i}$ = grass-soil concentration ratio, contaminant i (mg/kg wet grass per mg/kg soil)
UR_s = uptake rate of soil by cattle (kg/d)
IR_m = meat ingestion rate (g/kg-d)
F_r = fraction of cattle range associated with affected area
EF_{food} = exposure frequency for ingesting food products (day/year)
ED_{nc} = exposure duration, noncarcinogenic effects (year)
AT_{nc} = averaging time, noncarcinogenic effects (day)
$RfD_{ing,i}$ = ingestion reference dose, contaminant i (mg/kg-d)

Ingestion of Chicken

$$HQ = [C_{s,i} \times TF_{s\text{-}c,i} \times UR_f \times F_{s,f} \times IR_c \times EF_{food} \times ED_{nc} \times 0.001\ kg/g] / (AT_{nc} \times RfD_{ing,i})$$

Where
$C_{s,i}$ = concentration of contaminant i in soil of chicken enclosure (mg/kg soil)
$TF_{s\text{-}c,i}$ = soil-chicken transfer factor, contaminant i (mg/kg chicken per mg/day)
UR_f = uptake rate of dry feed (kg/day)
$F_{s,f}$ = fraction of soil in chicken feed
IR_c = chicken ingestion rate (g/kg-d)
EF_{food} = exposure frequency for ingesting food products (day/year)
ED_{nc} = exposure duration, noncarcinogenic effects (year)
AT_{nc} = averaging time, noncarcinogenic effects (day)
$RfD_{ing,i}$ = ingestion reference dose, contaminant i (mg/kg-d)

Ingestion of Eggs

$$HQ = [C_{s,i} \times TF_{s\text{-}e,\,i} \times UR_f \times F_{s,f} \times IR_e \times EF_{food} \times ED_{nc} \times 0.001\ kg/g] / (AT_{nc} \times RfD_{ing,i})$$

Where
- $C_{s,i}$ = concentration of contaminant i in soil of chicken enclosure (mg/kg soil)
- $TF_{s\text{-}e,\,i}$ = soil-egg transfer factor, contaminant i (mg/kg egg per mg/day)
- UR_f = uptake rate of dry feed (kg/day)
- $F_{s,f}$ = fraction of soil in chicken feed
- IR_e = egg ingestion rate (g/kg-d)
- EF_{food} = exposure frequency for ingesting food products (day/year)
- ED_{nc} = exposure duration, noncarcinogenic effects (year)
- AT_{nc} = averaging time, noncarcinogenic effects (day)
- $RfD_{ing,i}$ = ingestion reference dose, contaminant i (mg/kg-d)

Chemical Risk

A lifetime incremental cancer risk (ICR) is the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a chemical. ICR values for each chemical may be summed to calculate a total ICR for an exposure scenario. Because cancer risk is expressed as a probability averaged over a lifetime, exposure as a child and adult is integrated in these equations.

Soil Ingestion

$$ICR = [C_{s,i} \times ((IR_{s,site,a} \times EF_a \times ED_{a,carc} / BW_a) + (IR_{s,site,c} \times EF_c \times ED_c / BW_c)) \times SF_{ing,i} \times 10^{-6}\ kg/mg] / (AT_{carc})$$

Where
- $C_{s,i}$ = concentration of contaminant i in exposure area soil (mg/kg soil)
- $IR_{s,site,c}$ = child site-specific soil ingestion rate (mg of soil/day)
- EF_c = child exposure frequency (day/year)
- ED_c = child exposure duration (year)
- BW_c = child body weight (kg)
- $IR_{s,site,a}$ = adult site-specific soil ingestion rate (mg of soil/day)
- EF_a = adult exposure frequency (day/year)
- $ED_{a,carc}$ = adult exposure duration for carcinogenic effects (year)
- BW_a = adult body weight (kg)
- $SF_{ing,i}$ = ingestion slope factor, contaminant i $(mg/kg\text{-}d)^{-1}$
- AT_{carc} = averaging time, carcinogenic effects (day)

For the equation to calculate the site-specific daily soil ingestion rate ($IR_{s,site}$), see the soil ingestion equation for calculation of chemical hazard.

Dust Inhalation

$$ICR = [C_{s,i} \times ((InhR_a \times ET_a \times EF_a \times ED_{a,carc} / BW_a) + (InhR_c \times ET_c \times EF_c \times ED_c / BW_c)) \times SF_{inh,i}] / (PEF \times AT_{carc})$$

Where
- $C_{s,i}$ = concentration of contaminant i in source area soil (mg/kg soil)
- $InhR_c$ = child inhalation rate (m^3/hour)
- ET_c = child exposure time (hour/day)
- EF_c = child exposure frequency (day/year)
- ED_c = child exposure duration (year)
- BW_c = child body weight (kg)
- $InhR_a$ = adult inhalation rate (m^3/hour)
- ET_a = adult exposure time (hour/day)
- EF_a = adult exposure frequency (day/year)
- $ED_{a,carc}$ = adult exposure duration for carcinogenic effects (year)
- BW_a = adult body weight (kg)
- $SF_{inh,i}$ = slope factor for inhalation, contaminant i $(mg/kg\text{-}d)^{-1}$
- PEF = particulate emission factor (m^3/kg)
- AT_{carc} = averaging time, carcinogenic effects (day)

For the equation to calculate the particulate emission factor (PEF), see the dust inhalation equation for calculation of chemical hazard.

Dermal Absorption from Soil

$$ICR = [C_{s,i} \times ABS_i \times ((SA_c \times AF_c \times EF_{derm,c} \times ED_c / BW_c) + (SA_a \times AF_a \times EF_{derm,a} \times ED_{a,carc} / BW_a)) \times (SF_{ing,i} / F_{oral,i}) \times 10^{-6}\ kg/mg] / (AT_{carc})$$

Where
- $C_{s,i}$ = concentration of contaminant i in exposure area soil (mg/kg soil)
- ABS_i = absorption factor, contaminant i (unitless)
- SA_c = child exposed skin surface area (cm^2)
- AF_c = child soil adherence factor (mg/event)
- $EF_{derm,c}$ = child exposure frequency for dermal contact with soil (event/yr)
- ED_c = child exposure duration (year)
- BW_c = child body weight (kg)
- SA_a = adult exposed skin surface area (cm^2)
- AF_a = adult soil adherence factor (mg/event)
- $EF_{derm,a}$ = adult exposure frequency for dermal contact with soil (event/yr)
- $ED_{a,carc}$ = adult exposure duration for carcinogenic effects (year)
- BW_a = adult body weight (kg)
- $SF_{ing,i}$ = ingestion slope factor, contaminant i $(mg/kg\text{-}d)^{-1}$

$F_{oral,i}$ = oral absorption factor, contaminant i (unitless)

AT_{carc} = averaging time, carcinogenic effects (day)

Ingestion of Garden Produce or Wild Plant Products

$$ICR = [C_{s,i} \times K_{p\text{-}s,\,i} \times ((IR_v \times depth_{cz} / depth\_root_v) + (IR_f \times depth_{cz} / depth\_root_f)) \times EF_{food} \times (ED_{a,carc} + ED_c) \times SF_{ing,i} \times 0.001\ kg/g] / (AT_{carc})$$

Where

$C_{s,i}$ = concentration of contaminant i in garden, orchard, or plant collection area soil (mg/kg soil)

$K_{p\text{-}s,\,i}$ = plant:soil concentration ratio, contaminant i (mg/kg wet plant per mg/kg soil)

IR_v = ingestion rate of home-grown vegetables; wet weight (g/kg-day)

IR_f = ingestion rate of home-grown fruits; wet weight (g/kg-day)

$depth_{cz}$ = depth of contaminated zone (cm)

$depth\_root_v$ = effective rooting depth of garden vegetables; <= to $depth_{cz}$ (cm)

$depth\_root_f$ = effective rooting depth of fruit trees; <= to $depth_{cz}$ (cm)

EF_{food} = exposure frequency for ingesting food products (day/year)

$ED_{a,carc}$ = adult exposure duration for carcinogenic effects (year)

ED_c = child exposure duration (year)

$SF_{ing,i}$ = ingestion slope factor, contaminant i $(mg/kg\text{-}d)^{-1}$

AT_{carc} = averaging time, carcinogenic effects (day)

Note: The ratio $depth_{cz}$: depth_root is used for garden soils to account for the percentage of soil amendment or fill mixed with local (contaminated) soil. The value of this ratio is constrained to be one or less.

Beef Ingestion

$$ICR = [C_{s,i} \times TF_{s\text{-}b,\,i} \times ((UR_g \times K_{g\text{-}s,i}) + UR_s) \times IR_m \times F_r \times EF_{food} \times (ED_{a,carc} + ED_c) \times SF_{ing,i} \times 0.001\ kg/g] / (AT_{carc})$$

Where

$C_{s,i}$ = concentration of contaminant i in range area soil (mg/kg soil)

$TF_{s\text{-}b,\,i}$ = soil-beef transfer factor, contaminant i (mg/kg beef per mg/day)

UR_g = uptake rate of grass by cattle, wet weight (kg/day)

$K_{g\text{-}s,\,i}$ = grass-soil concentration ratio, contaminant i (mg/kg wet grass per mg/kg soil)

UR_s = uptake rate of soil by cattle (kg/d)

IR_m = meat ingestion rate (g/kg-d)

F_r = fraction of cattle range associated with affected area

EF_{food} = exposure frequency for ingesting food products (day/year)

$ED_{a,carc}$ = adult exposure duration for carcinogenic effects (year)

ED_c = child exposure duration (year)

$SF_{ing,i}$ = ingestion slope factor, contaminant i $(mg/kg\text{-}d)^{-1}$

AT_{carc} = averaging time, carcinogenic effects (day)

Ingestion of Chicken

$$ICR = [C_{s,i} \times TF_{s\text{-}c,\,i} \times UR_f \times F_{s,f} \times IR_c \times EF_{food} \times (ED_{a,carc} + ED_c) \times SF_{ing,i} \times 0.001\ kg/g] / (AT_{carc})$$

Where
- $C_{s,i}$ = concentration of contaminant i in soil of chicken enclosure (mg/kg soil)
- $TF_{s\text{-}c,\,i}$ = soil-chicken transfer factor, contaminant i (mg/kg chicken per mg/day)
- UR_f = uptake rate of dry feed (kg/day)
- $F_{s,f}$ = fraction of soil in chicken feed
- IR_c = chicken ingestion rate (g/kg-d)
- EF_{food} = exposure frequency for ingesting food products (day/year)
- $ED_{a,carc}$ = adult exposure duration for carcinogenic effects (year)
- ED_c = child exposure duration (year)
- $SF_{ing,i}$ = ingestion slope factor, contaminant i $(mg/kg\text{-}d)^{-1}$
- AT_{carc} = averaging time, carcinogenic effects (day)

Ingestion of Eggs

$$ICR = [C_{s,i} \times TF_{s\text{-}e,\,i} \times UR_f \times F_{s,f} \times IR_e \times EF_{food} \times (ED_{a,carc} + ED_c) \times SF_{ing,i} \times 0.001\ kg/g] / (AT_{carc})$$

Where
- $C_{s,i}$ = concentration of contaminant i in soil of chicken enclosure (mg/kg soil)
- $TF_{s\text{-}e,\,i}$ = soil-egg transfer factor, contaminant i (mg/kg chicken per mg/day)
- UR_f = uptake rate of dry feed (kg/day)
- $F_{s,f}$ = fraction of soil in chicken feed
- IR_e = egg ingestion rate (g/kg-d)
- EF_{food} = exposure frequency for ingesting food products (day/year)
- $ED_{a,carc}$ = adult exposure duration for carcinogenic effects (year)
- ED_c = child exposure duration (year)
- $SF_{ing,i}$ = ingestion slope factor, contaminant i $(mg/kg\text{-}d)^{-1}$
- AT_{carc} = averaging time, carcinogenic effects (day)

Hanover/Whitewater Creek Investigation Unit Risk-Based Screening Levels

Constituent	E1/E3 On-Site Residential		E1 Off-Site Residential		E1 Recreation/Resource Use		E2 Trespasser		E3 Recreational	
	Noncancer	Cancer	Noncancer	Cancer	Noncancer	Cancer	Noncancer	Cancer	Noncancer	Cancer
Aluminum	54000	NA[a]	54000	NA	150000	NA	unlimited[b]	NA	unlimited	NA
Antimony	29	NA	39	NA	66	NA	11000	NA	5500	NA
Arsenic	4.5	0.027	33	0.57	47	0.71	4700	26	3000	16
Barium	1100	NA	4300	NA	11000	NA	570000	NA	330000	NA
Beryllium	72	64	180	64	357	474	32000	4024	16000	2000
Boron	360	NA	470	NA	1200	NA	990000	NA	710000	NA
Cadmium	16	85	44	85	88	631	13000	5361	8800	2700
Chromium	31000	13	150000	13	190000	95	unlimited	806	unlimited	400
Cobalt	1900	NA	7300	NA	2800	NA	830000	NA	550000	NA
Copper	550	NA	1300	NA	1400	NA	700000	NA	420000	NA
Iron	2800	NA	39000	NA	54000	NA	unlimited	NA	unlimited	NA
Lead	400	NA	400	NA	400	NA	1000	NA	1000	NA
Manganese	890	NA	1000	NA	4000	NA	150000	NA	79000	NA
Mercury	7.8	NA	12	NA	0.58	NA	8100	NA	4100	NA
Molybdenum	110	NA	380	NA	430	NA	130000	NA	66000	NA
Nickel	1100	NA	1500	NA	2400	NA	410000	NA	230000	NA
Selenium	7.9	NA	510	NA	240	NA	130000	NA	66000	NA
Silver	90	NA	300	NA	570	NA	130000	NA	66000	NA
Thallium	1.8	NA	11	NA	13	NA	2200	NA	1100	NA
Vanadium	1100	NA	1200	NA	1800	NA	210000	NA	110000	NA
Zinc	660	NA	3300	NA	2200	NA	unlimited	NA	unlimited	NA

Note: Values are tabulated with two significant figures. Noncancer effects RBSL is the lower of either child or adult for scenarios with both receptors.

[a] NA = Not applicable, constituent does not have an EPA slope factor.

[b] unlimited = Value exceeds 1,000,000 mg/kg.

Input Parameter Values and References for Reasonable Maximum Exposure Calculations

Parameter	Unit	E1/E3 On-Site Residential		E1 Off-Site Residential		E1 Recreation/Resource Use		E2 Trespasser		E3 Recreational	
		Value	Reference	Value	Reference	Value	Reference	Value	Reference	Value	Reference
IRs_c	mg/d	200	EPA 1997 (note 1)	200	EPA 1997 (note 1)	400	EPA 1997 (note 2)	0	0-6 yr child not evaluated	0	0-6 yr child not evaluated
IRs_a	mg/d	50	EPA 1997 (note 3)	50	EPA 1997 (note 3)	50	EPA 1997 (note 3)	50	EPA 1997 (note 3)	50	EPA 1997 (note 3)
EF_c	d/yr	350	EPA 1991	350	EPA 1991	180	BPJ (a)	0	0-6 yr child not evaluated	0	0-6 yr child not evaluated
EF_a	d/yr	350	EPA 1991	350	EPA 1991	180	BPJ (a)	60	EPA Reg 6 1995	60	EPA Reg 6 1995
ED_c	yr	6	EPA 1991	6	EPA 1991	6	EPA 1991	0	0-6 yr child not evaluated	0	0-6 yr child not evaluated
ED_a_nc	yr	30	EPA 1991	30	EPA 1991	30	EPA 1991	30	EPA 1991	30	EPA 1991
ED_a_carc	yr	24	EPA 1991	24	EPA 1991	24	EPA 1991	30	EPA 1991	30	EPA 1991
InhR_c	m3/hr	0.42	EPA 1997 (note 4)	0.42	EPA 1997 (note 4)	1.2	EPA 1997 (note 5)	0	0-6 yr child not evaluated	0	0-6 yr child not evaluated
InhR_a	m3/hr	0.63	EPA 1997 (note 6)	0.63	EPA 1997 (note 6)	1.6	EPA 1997 (note 7)	1.6	EPA 1997 (note 7)	1.6	EPA 1997 (note 7)
ET_c	hr/d	22.4	BPJ (b)	22.4	BPJ (b)	2	BPJ (b)	0	0-6 yr child not evaluated	0	0-6 yr child not evaluated
ET_a	hr/d	19	BPJ (b)	19	BPJ (b)	2	BPJ (b)	1	BPJ (b)	2	BPJ (b)
EF_inh	d/yr	350	EPA 1991	350	EPA 1991	180	BPJ (a)	60	EPA Reg 6 1995	60	EPA Reg 6 1995
EF_derm_a	d/yr	350	EPA 1991	350	EPA 1991	180	BPJ (a)	60	EPA Reg 6 1995	60	EPA Reg 6 1995
EF_derm_c	d/yr	350	EPA 1991	350	EPA 1991	180	BPJ (a)	60	EPA Reg 6 1995	60	EPA Reg 6 1995
IR_gw_c	l/d	1.3	EPA 1997 (note 10)	-	pathway not applicable	-	pathway not applicable	-	pathway not applicable	-	pathway not applicable
IR_gw_a	l/d	2.3	EPA 1997 (note 11)	-	pathway not applicable	-	pathway not applicable	-	pathway not applicable	-	pathway not applicable
EF_gw	d/yr	350	EPA 1991	-	pathway not included	-	pathway not applicable	-	pathway not applicable	-	pathway not applicable
IR_sw_c	l/d	-	pathway not included	-	pathway not included	0.05	BPJ (g)	-	pathway not applicable	-	pathway not applicable

Parameter	Unit	E1/E3 On-Site Residential		E1 Off-Site Residential		E1 Recreation/Resource Use		E2 Trespasser		E3 Recreational	
		Value	Reference	Value	Reference	Value	Reference	Value	Reference	Value	Reference
EF_sw	d/yr	-	pathway not included	-	pathway not included	60	BPJ (h)	-	pathway not applicable	-	pathway not applicable
IR_v	g/kg-d	1.2	EPA 1997 (note 12)	1.2	EPA 1997 (note 12)	0.043	BPJ (c)	-	pathway not included	-	pathway not included
IR_f	g/kg-d	1.4	EPA 1997 (note 13)	1.4	EPA 1997 (note 13)	0.17	BPJ (c)	-	pathway not included	-	pathway not included
depth_cz	m	0.15	BPJ (d)	0.15	BPJ (i)	1	BPJ (j)	-	pathway not included	-	pathway not included
depth_root_v	m	0.3	BPJ (d)	0.45	BPJ (i)	1	BPJ (j)	-	pathway not included	-	pathway not included
depth_root_f	m	1	BPJ (k)	1	BPJ (k)	1	BPJ (j)	-	pathway not included	-	pathway not included
IR_m	g/kg-d	-	pathway not included	-	pathway not included	2.2	EPA 1997 (note 14)	-	pathway not included	-	pathway not included
F_r	unitless	-	pathway not included	-	pathway not included	0.1	BPJ (f)	-	pathway not included	-	pathway not included
IR_c	g/kg-d	1.3	EPA 1997 (note 15)	-	pathway not included	-	pathway not included	-	pathway not applicable	-	pathway not applicable
IR_e	g/kg-d	1.05	EPA 1997 (note 16)	-	pathway not included	-	pathway not included	-	pathway not applicable	-	pathway not applicable
EF_b	d/yr	365	(note 17)	365	(note 17)	365	(note 17)	-	pathway not applicable	-	pathway not applicable
BW_c	kg	17.4	EPA 1997 (note 18)	17.4	EPA 1997 (note 18)	17.4	EPA 1997 (note 18)	0	0-6 yr child not evaluated	0	0-6 yr child not evaluated
BW_a	kg	71.8	EPA 1997 (note 19)	71.8	EPA 1997 (note 19)	71.8	EPA 1997 (note 19)	71.8	EPA 1997 (note 19)	71.8	EPA 1997 (note 19)
SA_a	cm^2	5700	EPA 2001 (note 8)	5700	EPA 2001 (note 8)	5700	EPA 2001 (note 8)	5700	EPA 2001 (note 8)	5700	EPA 2001 (note 8)
SA_c	cm^2	2800	EPA 2001 (note 9)	2800	EPA 2001 (note 9)	2800	EPA 2001 (note 9)	-	0-6 yr child not evaluated	-	0-6 yr child not evaluated
AF_c	mg/cm^2-d	0.2	EPA 2001 (note 20)	0.2	EPA 2001 (note 20)	0.2	EPA 2001 (note 20)	-	pathway not included	-	pathway not included
AF_a	mg/cm^2-d	0.07	EPA 2001 (note 21)	0.07	EPA 2001 (note 21)	0.07	EPA 2001 (note 21)	0.07	EPA 2001 (note 21)	0.07	EPA 2001 (note 21)

Parameter	Unit	E1/E3 On-Site Residential		E1 Off-Site Residential		E1 Recreation/Resource Use		E2 Trespasser		E3 Recreational	
		Value	Reference	Value	Reference	Value	Reference	Value	Reference	Value	Reference
UR_g	kg/d	-	pathway not included	-	pathway not included	50	Baes et al. 1984 (note 22)	-	pathway not included	-	pathway not included
UR_s	kg/d	-	pathway not included	-	pathway not included	0.1	BPJ (e)	-	pathway not included	-	pathway not included
F_s,f	unitless	0.3	EPA 1993 (note 23)	-	pathway not included	-	pathway not applicable	-	pathway not applicable	-	pathway not applicable
UR_f	kg/d	0.1	Ng et al. 1982 (note 24)	-	pathway not included	-	pathway not included	-	pathway not included	-	pathway not included
AT_carc	yr	75	EPA 1997	75	EPA 1997	75	EPA 1997	75	EPA 1997	75	EPA 1997
AT_nc	yr	ED	equal to exposure duration	ED	equal to exposure duration	ED	equal to exposure duration	ED	equal to exposure duration	ED	equal to exposure duration
T_site_out,c	hr/d	3	EPA 1997 (note 25)	3	EPA 1997 (note 25)	2	BPJ (b)	-	0-6 yr child not evaluated	-	0-6 yr child not evaluated
T_site_out,a	hr/d	3	EPA 1997 (note 26)	3	EPA 1997 (note 26)	2	BPJ (b)	1	BPJ (b)	2	BPJ (b)
T_sleeping,c	hr/d	11.5	EPA 1997 (note 27)	11.5	EPA 1997 (note 27)	11.5	EPA 1997 (note 27)	-	0-6 yr child not evaluated	-	0-6 yr child not evaluated
T_sleeping,a	hr/d	8	EPA 1997 (note 28)	8	EPA 1997 (note 28)	8	EPA 1997 (note 28)	8	EPA 1997 (note 28)	8	EPA 1997 (note 28)
T_site_in,c	hr/d	19.4	EPA 1997 (note 29)	19.4	EPA 1997 (note 29)	0	no indoor exposure	-	0-6 yr child not evaluated	-	0-6 yr child not evaluated
T_site_in,a	hr/d	16	EPA 1997 (note 30)	16	EPA 1997 (note 30)	0	no indoor exposure	0	no indoor exposure	0	no indoor exposure
T_in,c	hr/d	19.4	BPJ (l)	19.4	BPJ (l)	19.4	BPJ (l)	-	0-6 yr child not evaluated	-	0-6 yr child not evaluated
T_in,a	hr/d	21	EPA 1997 (note 31)	21	EPA 1997 (note 31)	21	EPA 1997 (note 31)	21	EPA 1997 (note 31)	21	EPA 1997 (note 31)
T_out,c	hr/d	4.6	(note 32)	4.6	(note 32)	4.6	(note 32)	-	0-6 yr child not evaluated	-	0-6 yr child not evaluated
T_out,a	hr/d	3	(note 32)	3	(note 32)	3	(note 32)	3	(note 32)	3	(note 32)
E_out,c	unitless	10	Kissel et al. 1996 (note 33)	10	Kissel et al. 1996 (note 33)	10	Kissel et al. 1996 (note 33)	-	0-6 yr child not evaluated	-	0-6 yr child not evaluated
E_out,a	unitless	10	Kissel et al. 1996 (note 33)	10	Kissel et al. 1996 (note 33)	10	Kissel et al. 1996 (note 33)	10	Kissel et al. 1996 (note 33)	10	Kissel et al. 1996 (note 33)

Notes

1. Conservative estimate of the mean; assumes 100% of daily soil ingestion is of soil from the affected area.
2. Upper percentile estimate; assumes 100% of daily soil ingestion is of soil from the affected area.
3. Central tendency estimate, no upper-bound provided; assumes 100% of daily soil ingestion is of soil from the affected area.
4. Recommended mean value for children ages 6-8 years.
5. Recommended short-term child exposure value for moderate activities.
6. Recommended mean value for adult men.
7. Recommended short-term adult exposure value for moderate activities.
8. Recommended value for both RME and CTE conditions; RAGS, Part E, Section 3.2 (Sept 2001). Adult exposed skin surface area corresponds to short sleeves, short pants, and shoes.
9. Recommended value for both RME and CTE conditions; RAGS, Part E, Section 3.2 (Sept 2001). Child exposed skin surface area corresponds to short sleeves, short pants, and no shoes.
10. 90th percentile recommended value for children age 1-10 year; Table 3-30.
11. 90th percentile recommended value for adults; Table 3-30.
12. 75th percentile of seasonally adjusted consumer intake of homegrown vegetables for Western U.S., corrected by 18% average preparation loss for corn, pumpkin, peppers, and tomatoes; Tables 13-33 and 13-7.
13. 75th percentile of seasonally adjusted consumer intake of homegrown fruit for Western U.S., corrected by 23% average preparation loss for apples, pears, and peaches; Tables 13-33 and 13-6.
14. 75th percentile value of annual-average home-produced beef intake for Western U.S., corrected by 24% mean preparation loss for beef; Tables 13-36 and 13-5.
15. 75th percentile value of annual-average home-produced poultry intake for Western U.S., corrected by 31% mean preparation loss for chicken; Tables 13-55 and 13-5.
16. 75th percentile value of annual-average home-produced egg intake for Western U.S.; Table 13-43.
17. An exposure frequency of 365 day/year is used for biotic products because intake values are annual averages.
18. Mean body weight of male and female children, age 4; Table 7-3.
19. Recommended mean body weight of adult; Chapter 7.3.
20. Recommended RME value; RAGS, Part E, Section 3.2 (Sept 2001). Child AF value pertains to both 95th percentile for day-care children (average activity) or 50th percentile for children playing in wet soil (high-exposure activity).
21. Recommended RME value; RAGS, Part E, Section 3.2 (Sept 2001). Adult AF value based on 50th percentile for high-exposure activity (gardening).
22. Wet feed consumption rate, p. 49.
23. Based on fraction of inorganic grit in the diet of the American Woodcock.
24. Approximate dry matter intake for broiler chickens and laying hens.
25. Table 15-120: Approximate 75th percentile of time at home in the yard for a child age 1-6 years.
26. Table 15-120: Approximate 75th percentile of time at home in the yard for adult age categories.
27. Table 15-83: Age-weighted 50th percentile of time spent sleeping/napping for child age 1-6 years.
28. Table 15-83: 50th percentile of time spent sleeping/napping for adult age 18-64 years.
29. Table 15-131: Age-weighted 50th percentile of time spent indoors in a residence for child age 1-6 years.
30. Table 15-131: Approximate 50th percentile of time spent indoors in a residence for adult age 5-64 years.

31. Section 15.4.1: Recommended value for time spent indoors in all locations for an adult over age 12.
32. Calculated as 24 hours per day minus time indoors.
33. Based on approximate tenfold difference in geometric mean of soil loading on hands between classes of soil-contact activities (assumes outdoor activities result in higher contact rate).

Best professional judgment (BPJ) definitions

BPJ (a): Assumes an individual is in the affected area every other day; high frequency because residence may be in or adjacent to IU.

BPJ (b): Assumption for average daily time spent within affected area; consistent with residential times specified for soil ingestion calculations.

BPJ (c): Calculated using recommended mean value for total vegetable or fruit intake rate, Chapter 9.3, Assuming 5% of total intake of fruits, and 1% of vegetables, could be gathered from affected area

BPJ (d): Assumes that native soil has been amended 50% with non-native soil for garden use

BPJ (e): Accounts for direct soil ingestion by cattle during grazing, value suggested by Espanola Natural Resource Conservation Service office

BPJ (f): Assumes affected area is 10% of entire cattle range and no supplemental feed is used

BPJ (g): Assumption of reasonable maximum surface water ingestion rate while playing

BPJ (h): Assumption of the reasonable maximum number of days a child with access to a surface water source plays there in a year

BPJ (i): Assumes that fill brought to homesite for grading comprises only one-third of garden soil.

BPJ (j): Conservatively assumes that contamination is uniform throughout root zone.

BPJ (k): Assumed effective rooting depth for fruit trees.

BPJ (l): Assumes all indoor time is spent at home; approximately equal to indoor time recommended for children < age 12 in Section 15.4.1.

References

(EPA 1991) United States Environmental Protection Agency. 1991. Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual Supplemental Guidance Standard Default Exposure Factors. OSWER Directive 9285.6-03. Office of Emergency and Remedial Response, Washington, D.C.

(EPA 1992) United States Environmental Protection Agency. 1992. Dermal Exposure Assessment: Principles and Application. Interim Report. EPA/600/8- 91/011B. Office of Research and Development, Washington, D.C.

(EPA 1993) United States Environmental Protection Agency. December 1993. Wildlife Exposure Factors Handbook, Volume I of II. EPA/600/R-93/187a. Office of Research and Development, Washington, D.C.

(EPA Reg 6 1995) United States Environmental Protection Agency, Region VI. Supplemental Region VI Risk Assessment Guidance.

(EPA 1997) United States Environmental Protection Agency. 1997. Exposure Factors Handbook, Volume I, II, or III. EPA/600/P-95/002F. Office of Research and Development, Washington, D.C.

(EPA 2001) Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim. EPA/540/R/99/005, OSWER 9285.7-02EP, September 2001.

(Baes et al. 1984) Baes, C. F., III, Sharp, R. D., Sjoreen, A. L., and Shor, R. W. 1984. A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture. ORNL-5786. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

(Kissel et al. 1996) Kissel, J. C, Richter, K. Y., and Fenske, R. A. 1996. Field Measurements of Dermal Soil Loading Attributable to Various Activities: Implications for Exposure Assessment. Risk Analysis, Vol. 16, No. 1.

(Ng et al. 1982) Ng, Y. C., Colsher, C. S., and Thompson, S. E. Transfer Coefficients for Assessing The Dose from Radionuclides in Meat and Eggs, Final Report NUREG/CR-2976, Lawrence Livermore National Laboratory, Livermore, California.

(Wang et al. 1993) Wang, Y.-Y., Biwer, B. M., and Yu, C., 'A Compilation of Radionuclide Transfer Factors for the Plant, Meat, Milk, and Aquatic Food Pathways and the Suggested Default Values', Argonne National Laboratory, August 1993.

Input Parameter Values and References for Central Tendency Estimate Calculations

Parameter	Unit	E1/E3 On-Site Residential		E1 Off-Site Residential		E1 Recreation/ Resource Use		E2 Trespasser		E3 Recreational	
		Value	Reference	Value	Reference	Value	Reference	Value	Reference	Value	Reference
IRs_c	mg/d	100	EPA 1997 (note 1)	100	EPA 1997 (note 1)	100	EPA 1997 (note 1)	0	0-6 yr child not evaluated	0	0-6 yr child not evaluated
IRs_a	mg/d	50	EPA 1997 (note 2)	50	EPA 1997 (note 2)	50	EPA 1997 (note 2)	50	EPA 1997 (note 2)	50	EPA 1997 (note 2)
EF_s,c	d/yr	350	EPA 1991	350	EPA 1991	100	BPJ (a)	0	0-6 yr child not evaluated	0	0-6 yr child not evaluated
EF_s,a	d/yr	350	EPA 1991	350	EPA 1991	100	BPJ (a)	60	EPA Reg 6 1995	60	EPA Reg 6 1995
ED_c	yr	6	EPA 1991	6	EPA 1991	6	EPA 1991	0	0-6 yr child not evaluated	0	0-6 yr child not evaluated
ED_a_nc	yr	9	EPA 1997 (note 3)	9	EPA 1997 (note 3)	9	EPA 1997 (note 3)	9	EPA 1997 (note 3)	9	EPA 1997 (note 3)
ED_a_carc	yr	3	EPA 1997 (note 3)	3	EPA 1997 (note 3)	3	EPA 1997 (note 3)	9	EPA 1997 (note 3)	9	EPA 1997 (note 3)
InhR_c	m3/hr	0.33	EPA 1997 (note 4)	0.33	EPA 1997 (note 4)	0.8	EPA 1997 (note 5)	0	0-6 yr child not evaluated	0	0-6 yr child not evaluated
InhR_a	m3/hr	0.63	EPA 1997 (note 6)	0.63	EPA 1997 (note 6)	1.6	EPA 1997 (note 7)	1.6	EPA 1997 (note 7)	1.6	EPA 1997 (note 7)
ET_c	hr/d	21.1	BPJ (b)	21.1	BPJ (b)	2	BPJ (b)	0	0-6 yr child not evaluated	0	0-6 yr child not evaluated
ET_a	hr/d	17.5	BPJ (b)	17.5	BPJ (b)	1	BPJ (b)	1	BPJ (b)	1	BPJ (b)
EF_inh	d/yr	350	EPA 1991	350	EPA 1991	100	BPJ (a)	60	EPA Reg 6 1995	60	EPA Reg 6 1995
EF_derm_a	d/yr	350	EPA 1991	350	EPA 1991	100	BPJ (a)	60	EPA Reg 6 1995	60	EPA Reg 6 1995
EF_derm_c	d/yr	350	EPA 1991	350	EPA 1991	100	BPJ (a)	60	EPA Reg 6 1995	60	EPA Reg 6 1995
IR_gw_c	l/d	0.74	EPA 1997 (note 10)	-	pathway not applicable	-	pathway not applicable	-	pathway not applicable	-	pathway not applicable
IR_gw_a	l/d	1.4	EPA 1997 (note 11)	-	pathway not applicable	-	pathway not applicable	-	pathway not applicable	-	pathway not applicable
EF_gw	d/yr	350	EPA 1991	-	pathway not included	-	pathway not applicable	-	pathway not applicable	-	pathway not applicable
IR_sw_c	l/d	-	pathway not included	-	pathway not included	0.01	BPJ (g)	-	pathway not applicable	-	pathway not applicable

Parameter	Unit	E1/E3 On-Site Residential		E1 Off-Site Residential		E1 Recreation/ Resource Use		E2 Trespasser		E3 Recreational	
		Value	Reference	Value	Reference	Value	Reference	Value	Reference	Value	Reference
EF_sw	d/yr	-	pathway not included	-	pathway not included	30	BPJ (h)	-	pathway not applicable	-	pathway not applicable
IR_v	g/kg-d	0.40	EPA 1997 (note 12)	0.40	EPA 1997 (note 12)	0.0215	BPJ (c)	-	pathway not included	-	pathway not included
IR_f	g/kg-d	0.53	EPA 1997 (note 13)	0.53	EPA 1997 (note 13)	0.068	BPJ (c)	-	pathway not included	-	pathway not included
depth_cz	m	0.15	BPJ (d)	0.15	BPJ (i)	1	BPJ (j)	-	pathway not included	-	pathway not included
depth_root_v	m	0.3	BPJ (d)	0.45	BPJ (i)	1	BPJ (j)	-	pathway not included	-	pathway not included
depth_root_f	m	1	BPJ (k)	1	BPJ (k)	1	BPJ (j)	-	pathway not included	-	pathway not included
IR_m	g/kg-d	-	pathway not included	-	pathway not included	1.2	EPA 1997 (note 14)	-	pathway not included	-	pathway not included
F_r	unitless	-	pathway not included	-	pathway not included	0.1	BPJ (f)	-	pathway not included	-	pathway not included
IR_c	g/kg-d	0.70	EPA 1997 (note 15)	-	pathway not included	-	pathway not included	-	pathway not applicable	-	pathway not applicable
IR_e	g/kg-d	0.67	EPA 1997 (note 16)	-	pathway not included	-	pathway not included	-	pathway not applicable	-	pathway not applicable
EF_b	d/yr	365	(note 17)	365	(note 17)	365	(note 17)	-	pathway not applicable	-	pathway not applicable
BW_c	kg	17.4	EPA 1997 (note 18)	17.4	EPA 1997 (note 18)	17.4	EPA 1997 (note 18)	0	0-6 yr child not evaluated	0	0-6 yr child not evaluated
BW_a	kg	71.8	EPA 1997 (note 19)	71.8	EPA 1997 (note 19)	71.8	EPA 1997 (note 19)	71.8	EPA 1997 (note 19)	71.8	EPA 1997 (note 19)
SA_a	cm^2	5700	EPA 2001 (note 8)	5700	EPA 2001 (note 8)	5700	EPA 2001 (note 8)	5700	EPA 2001 (note 8)	5700	EPA 2001 (note 8)
SA_c	cm^2	2800	EPA 2001 (note 9)	2800	EPA 2001 (note 9)	2800	EPA 2001 (note 9)	-	0-6 yr child not evaluated	-	0-6 yr child not evaluated
AF_c	mg/cm^2-d	0.04	EPA 2001 (note 20)	0.04	EPA 2001 (note 20)	0.04	EPA 2001 (note 20)	-	pathway not included	-	pathway not included
AF_a	mg/cm^2-d	0.01	EPA 2001 (note 21)	0.01	EPA 2001 (note 21)	0.01	EPA 2001 (note 21)	0.01	EPA 2001 (note 21)	0.01	EPA 2001 (note 21)

Parameter	Unit	E1/E3 On-Site Residential		E1 Off-Site Residential		E1 Recreation/ Resource Use		E2 Trespasser		E3 Recreational	
		Value	Reference	Value	Reference	Value	Reference	Value	Reference	Value	Reference
UR_g	kg/d	-	pathway not included	-	pathway not included	50	Baes et al.1984 (note 22)	-	pathway not included	-	pathway not included
UR_s	kg/d	-	pathway not included	-	pathway not included	0.1	BPJ (e)	-	pathway not included	-	pathway not included
F_s,f	unitless	0.3	EPA 1993 (note 23)	-	pathway not included	-	pathway not applicable	-	pathway not applicable	-	pathway not applicable
UR_f	kg/d	0.1	Ng et al. 1982 (note 24)	-	pathway not included	-	pathway not included	-	pathway not included	-	pathway not included
AT_carc	yr	75	EPA 1997	75	EPA 1997	75	EPA 1997	75	EPA 1997	75	EPA 1997
AT_nc	yr	ED	equal to exposure duration	ED	equal to exposure duration	ED	equal to exposure duration	ED	equal to exposure duration	ED	equal to exposure duration
T_site_out,c	hr/d	1.7	EPA 1997 (note 25)	1.7	EPA 1997 (note 25)	2	BPJ (b)	-	0-6 yr child not evaluated	-	0-6 yr child not evaluated
T_site_out,a	hr/d	1.5	EPA 1997 (note 26)	1.5	EPA 1997 (note 26)	1	BPJ (b)	1	BPJ (b)	1	BPJ (b)
T_sleeping,c	hr/d	11.5	EPA 1997 (note 27)	11.5	EPA 1997 (note 27)	11.5	EPA 1997 (note 27)	-	0-6 yr child not evaluated	-	0-6 yr child not evaluated
T_sleeping,a	hr/d	8	EPA 1997 (note 28)	8	EPA 1997 (note 28)	8	EPA 1997 (note 28)	8	EPA 1997 (note 28)	8	EPA 1997 (note 28)
T_site_in,c	hr/d	19.4	EPA 1997 (note 29)	19.4	EPA 1997 (note 29)	0	no indoor exposure	-	0-6 yr child not evaluated	-	0-6 yr child not evaluated
T_site_in,a	hr/d	16	EPA 1997 (note 30)	16	EPA 1997 (note 30)	0	no indoor exposure	0	no indoor exposure	0	no indoor exposure
T_in,c	hr/d	19.4	BPJ (l)	19.4	BPJ (l)	19.4	BPJ (l)	-	0-6 yr child not evaluated	-	0-6 yr child not evaluated
T_in,a	hr/d	21	EPA 1997 (note 31)	21	EPA 1997 (note 31)	21	EPA 1997 (note 31)	21	EPA 1997 (note 31)	21	EPA 1997 (note 31)
T_out,c	hr/d	4.6	(note 32)	4.6	(note 32)	4.6	(note 32)	-	0-6 yr child not evaluated	-	0-6 yr child not evaluated
T_out,a	hr/d	3	(note 32)	3	(note 32)	3	(note 32)	3	(note 32)	3	(note 32)

Parameter	Unit	E1/E3 On-Site Residential		E1 Off-Site Residential		E1 Recreation/ Resource Use		E2 Trespasser		E3 Recreational	
		Value	Reference	Value	Reference	Value	Reference	Value	Reference	Value	Reference
E_out,c	unitless	10	Kissel et al. 1996 (note 33)	10	Kissel et al. 1996 (note 33)	10	Kissel et al. 1996 (note 33)	-	0-6 yr child not evaluated	-	0-6 yr child not evaluated
E_out,a	unitless	10	Kissel et al. 1996 (note 33)	10	Kissel et al. 1996 (note 33)	10	Kissel et al. 1996 (note 33)	10	Kissel et al. 1996 (note 33)	10	Kissel et al. 1996 (note 33)

Notes

1. Mean recommended value; assumes 100% of daily soil ingestion is of soil from the affected area.
2. Central tendency estimate; assumes 100% of daily soil ingestion is of soil from the affected area.
3. Average of population mobility from 1993 US Census is 9 years, Table 15-176 - for carcinogens, child and adult intakes are summed.
4. Calculated according to age-weighted rates provided in Table 5-23 for children through age 6 ($2/6*6.6m^3/d + 3/6*8.3m^3/d + 1/6*10m^3/d$).
5. Recommended short-term child (age 1-18) exposure value for moderate activities; multiplied by 2/3 to reflect lower rate for children age 1-6 recorded in long-term recommendations.
6. Recommended mean value for adult men.
7. Recommended short-term adult exposure value for moderate activities.
8. Recommended value for both RME and CTE conditions; RAGS, Part E, Section 3.2 (Sept 2001). Adult exposed skin surface area corresponds to short sleeves, short pants, and shoes.
9. Recommended value for both RME and CTE conditions; RAGS, Part E, Section 3.2 (Sept 2001). Child exposed skin surface area corresponds to short sleeves, short pants, and no shoes.
10. Mean recommended value for children age 1-10 year; Table 3-30.
11. Mean recommended value for adults; Table 3-30.
12. 50th percentile of seasonally adjusted consumer intake of homegrown vegetables for Western U.S., corrected by 18% average preparation loss for corn, pumpkin, peppers, and tomatoes; Tables 13-33 and 13-7.
13. 50th percentile of seasonally adjusted consumer intake of homegrown fruit for Western U.S., corrected by 23% average preparation loss for apples, pears, and peaches; Tables 13-33 and 13-6.
14. 50th percentile value of annual-average home-produced beef intake for Western U.S., corrected by 24% mean preparation loss for beef; Tables 13-36 and 13-5.
15. 50th percentile value of annual-average home-produced poultry intake for Western U.S., corrected by 31% mean preparation loss for chicken; Tables 13-55 and 13-5.
16. 50th percentile value of annual-average home-produced egg intake for Western U.S.; Table 13-43.
17. An exposure frequency of 365 day/year is used for biotic products because intake values are annual averages.
18. Mean body weight of male and female children, age 4; Table 7-3.
19. Recommended mean body weight of adult; Chapter 7.3.
20. RAGS, Part E, Exhibit C-3 and Exhibit 3-5 (Sept 2001). Child AF based on geometric mean for children ages 8-12 playing in dry soil.
21. RAGS, Part E, Exhibit C-3 and Exhibit 3-5 (Sept 2001). Adult AF value based on geometric mean for average exposure activity (groundskeeper).

22. Wet feed consumption rate, p. 49.
23. Based on fraction of inorganic grit in the diet of the American Woodcock.
24. Approximate dry matter intake for broiler chickens and laying hens.
25. Table 15-120: Age-weighted 50th percentile of time at home in the yard for a child age 1-6 years.
26. Table 15-120: Approximate 50th percentile of time at home in the yard for adult age categories.
27. Table 15-83: Age-weighted 50th percentile of time spent sleeping/napping for child age 1-6 years.
28. Table 15-83: 50th percentile of time spent sleeping/napping for adult age 18-64 years.
29. Table 15-131: Age-weighted 50th percentile of time spent indoors in a residence for child age 1-6 years.
30. Table 15-131: Approximate 50th percentile of time spent indoors in a residence for adult age 5-64 years.
31. Section 15.4.1: Recommended value for time spent indoors in all locations for an adult over age 12.
32. Calculated as 24 hours per day minus time indoors.
33. Based on approximate tenfold difference in geometric mean of soil loading on hands between classes of soil-contact activities (assumes outdoor activities result in higher contact rate).

Best professional judgment (BPJ) definitions

BPJ (a): Assumes an individual is in the affected area on average twice per week; higher frequency than EPA Region 6 recommendation because overbank residences are adjacent to the stream channel and the IU may serve as an extended yard.

BPJ (b): Assumption for average daily time spent within affected area; consistent with residential times specified for soil ingestion calculations.

BPJ (c): Calculated using recommended mean value for total vegetable or fruit intake rate, Chapter 9.3, Assuming 2% of total intake of fruits, and 0.5% of vegetables, could be gathered from affected area

BPJ (d): Assumes that native soil has been amended 50% with non-native soil for garden use.

BPJ (e): Accounts for direct soil ingestion by cattle during grazing, value suggested by Espanola Natural Resource Conservation Service office

BPJ (f): Assumes affected area is 10% of entire cattle range and no supplemental feed is used

BPJ (g): Assumption of average inadvertent surface water ingestion rate during play

BPJ (h): Assumption of the average number of days a child with access to a surface water source plays there in a year

BPJ (i): Assumes that fill brought to homesite for grading comprises only one-third of garden soil.

BPJ (j): Conservatively assumes that contamination is uniform throughout root zone.

BPJ (k): Assumed effective rooting depth for fruit trees.

References

(EPA 1991) United States Environmental Protection Agency. 1991. Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual Supplemental Guidance Standard Default Exposure Factors. OSWER Directive 9285.6-03. Office of Emergency and Remedial Response, Washington, D.C.

(EPA 1992) United States Environmental Protection Agency. 1992. Dermal Exposure Assessment: Principles and Application. Interim Report. EPA/600/8- 91/011B. Office of Research and Development, Washington, D.C.

(EPA 1993) United States Environmental Protection Agency. December 1993. Wildlife Exposure Factors Handbook, Volume I of II. EPA/600/R-93/187a. Office of Research and Development, Washington, D.C.

(EPA Reg 6 1995) United States Environmental Protection Agency, Region VI. Supplemental Region VI Risk Assessment Guidance.

(EPA 1997) United States Environmental Protection Agency. 1997. Exposure Factors Handbook, Volume I, II, or III. EPA/600/P-95/002F. Office of Research and Development, Washington, D.C.

(EPA 2001) Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim. EPA/540/R/99/005, OSWER 9285.7-02EP, September 2001.

(Baes et al. 1984) Baes, C. F., III, Sharp, R. D., Sjoreen, A. L., and Shor, R. W. 1984. A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture. ORNL-5786. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

(Kissel et al. 1996) Kissel, J. C, Richter, K. Y., and Fenske, R. A. 1996. Field Measurements of Dermal Soil Loading Attributable to Various Activities: Implications for Exposure Assessment. Risk Analysis, Vol. 16, No. 1.

(Ng et al. 1982) Ng, Y. C., Colsher, C. S., and Thompson, S. E. Transfer Coefficients for Assessing The Dose from Radionuclides in Meat and Eggs, Final Report NUREG/CR-2976, Lawrence Livermore National Laboratory, Livermore, California.

(Wang et al. 1993) Wang, Y.-Y., Biwer, B. M., and Yu, C., 'A Compilation of Radionuclide Transfer Factors for the Plant, Meat, Milk, and Aquatic Food Pathways and the Suggested Default Values', Argonne National Laboratory, August 1993.

Transfer Factors and Vegetation-Soil Concentration Ratios

Chemical Contaminant	Baes Br Value (unitless)[a]	Plant/Soil Conc Ratio (Kp-s) (unitless)[b]	Grass/Soil Conc Ratio (Kg-s) (unitless)[c]	Beef Transfer Factor (TFs-b) (mg/kg beef per mg/d)	Chicken Transfer Factor (TFs-c) (mg/kg chicken per mg/d)	Egg Transfer Factor (TFs-e) (mg/kg egg per mg/d)
Aluminum	0.00065	0.0000975	0.000728	0.0015	NA[d]	NA
Antimony	0.03	0.0045	0.0182	0.001	0.006	0.07
Arsenic	0.006	0.0009	0.0364	0.002	0.83	0.8
Barium	0.015	0.00225	0.0182	0.00015	0.00081	1.5
Beryllium	0.0015	0.000225	0.0182	0.001	0.4	0.02
Boron	2	0.3	0.728	0.0008	NA	NA
Cadmium	0.15	0.0225	0.182	0.00055	0.84	0.1
Chromium	0.0045	0.000675	0.0182	0.0055	0.2	0.8
Cobalt	0.007	0.00105	0.0728	0.02	0.5	0.1
Copper	0.25	0.0375	0.1456	0.01	0.51	0.49
Iron	0.001	0.00015	0.000546	0.02	1.5	1.3
Lead	0.009	0.00135	0.0182	0.0003	0.2	0.8
Manganese	0.05	0.0075	0.16744	0.0004	0.05	0.065
Mercury	0.2	0.03	0.182	0.25	0.011	0.2
Molybdenum	0.06	0.009	0.0728	0.006	0.19	0.78
Nickel	0.06	0.009	0.02002	0.006	0.001	0.1
Selenium	0.025	0.00375	0.091	0.015	8.5	9.3
Silver	0.1	0.015	0.0182	0.003	0.5	0.5
Thallium	0.0004	0.00006	0.000728	0.04	0.3	0.8
Vanadium	0.003	0.00045	0.001001	0.0025	NA	NA
Zinc	0.9	0.135	0.091	0.1	6.5	2.6

[a] Br values for reproductive portions of plants, dry weight, taken from Figure 2.2 of Baes et al. 1984.

[b] mg/kg wet plant per mg/kg dry soil; converted from original dry weight values using dry-to-wet conversion factor of 0.15 from 1) Hurley Soils HHRA, pp. 76 and 2) conservative average for common fruits and vegetables in EFH, Vol II, Table 9-27 (EPA 1997).

[c] mg/kg wet plant per mg/kg dry soil; converted from original dry weight values using dry-to-wet ratio of 0.182 for grass (Wang et al. 1993; Table 2).

[d] NA = Not available.

Notes

Unless otherwise noted below, grass/soil values for metals are suggested values taken from Table 10 of Wang et al. (1993)

Transfer factors for beef are Ff values, taken from Figure 2.25 of Baes et al. 1984.

Poultry and egg transfer factors (wet-weight basis) are defaults from Table 6.18 of a DandD computer code guidance document (Kennedy and Strenge, 1992).
These factors are primarily taken from those used in the GENII code by PNNL (Napier 1988) which, in turn, derive partially from Ng et al. (1982).
These transfer factors, which are feed-to-chicken or egg factors, have been applied as soil-to-chicken or soil-to-egg factors even though bioavailability from dirt and from feed likely differs.

Aluminum: grass/soil ratio (Bv) from Baes et al. (1984).

Boron: grass/soil ratio (Bv) from Baes et al. (1984).

Thallium: grass/soil ratio (Bv) from Baes et al. (1984).

Vanadium: grass/soil ratio (Bv) from Baes et al. (1984).

References

(Wang et al. 1993) 'A Compilation of Radionuclide Transfer Factors for the Plant, Meat, Milk, and Aquatic Food Pathways and the Suggested Default Values', Wang, Y.-Y., Biwer, BM, and Yu, C, Argonne National Laboratory, August 1993.

(Baes et al. 1984) 'A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides Through Agriculture', Prepared for the U.S. Department of Energy, Health and Safety Research Division, Oak Ridge National Laboratory, Tennessee, September 1984.

(Kennedy and Strenge 1992) 'Residual Radioactive Contamination From Decommissioning - Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent: Final Report', NUREG/CR-5512-V1, Prepared for the U.S. Nuclear Regulatory Commission by Pacific Northwest Laboratory, October 1992.

(Napier 1988) 'GENII - The Hanford Environmental Radiation Dosimetry Software System; Volume 2: User's Manual', report PNL-6584, Vol. 2, Pacific Northwest Laboratory, Richland WA.

(Ng et al. 1982) 'Transfer Coefficients for Assessing the Dose from Radionuclides in Meat and Eggs', report NUREG/CR-2976, UCID-19464, Lawrence Livermore National Laboratory, Livermore, CA.

(EPA 1997) United States Environmental Protection Agency. 1997. 'Exposure Factors Handbook, Volume II', EPA/600/P-95/002F, Office of Research and Development, Washington, D.C.

Dermal And Gastrointestinal Absorption Fractions

Chemical Contaminant	Dermal Absorption Fraction (ABS) (unitless)	Gastrointestinal Absorption Fraction (GI_{abs}) (unitless)
Aluminum	0	1
Antimony	0	0.15
Arsenic	0.03	1
Barium	0	0.07
Beryllium	0	0.007
Boron	0	1
Cadmium	0.001	0.025
Chromium	0	0.015
Cobalt	0	1
Copper	0	1
Iron	0	1
Lead	0	1
Manganese	0	0.04
Mercury	0	0.07
Molybdenum	0	1
Nickel	0	0.04
Selenium	0	1
Silver	0	0.04
Thallium	0	1
Vanadium/	0	0.026
Zinc	0	1

Notes

Chromium oral absorption value (GI_{abs}) reflects assumed 6:1 ratio of CrIII to CrVI oxidation states.

Copper oral reference dose based on gastrointestinal irritation; doesn't apply to dermal uptake.

Mercury as mercuric chloride or other soluble salts.

Chemical-specific ABS values taken from Exhibit 3-4 of EPA's draft Dermal Risk Assessment Guidance for Superfund (EPA 2001)
Section 3.2.2.4 of EPA 2001 states that absorption should not be quantified with generic ABS values for other metals.

Chemical-specific GI_{abs} values taken from Exhibit 4-1 of EPA's draft Dermal Risk Assessment Guidance for Superfund (EPA 2001)
Section 4.2 of EPA 2001 states that GI absorption should be set at 100% for inorganic chemicals without specific values in Exhibit 4-1.

Reference

EPA 2001. Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim. EPA/540/R/99/005, OSWER 9285.7-02EP, September 2001.

Oral and Inhalation Toxicity Values

Chemical Toxicity Values								
	Oral RfD		Inhal RfD		Oral SF		Inhal SF	
Contaminant	(mg/kg-d)	Source	(mg/kg-d)	Source	$(mg/kg\text{-}d)^{-1}$	Source	$(mg/kg\text{-}d)^{-1}$	Source
Aluminum	1.0E+00	NCEA	1.0E-03	NCEA	NA*		NA	
Antimony	4.0E-04	IRIS	NA		NA		NA	
Arsenic	3.0E-04	IRIS	NA		1.5E+00	IRIS	1.5E+01	IRIS
Barium	7.0E-02	IRIS	1E-04	HEAST alt	NA		NA	
Beryllium	2.0E-03	IRIS	5.7E-06	IRIS	NA		8.4E+00	IRIS
Boron	9.0E-02	IRIS	NA		NA		NA	
Cadmium	1.0E-03	IRIS	3.7E-05	Gradient 2000	NA		6.3E+00	IRIS
Chromium	1.3E+00	IRIS	NA		NA		4.2E+01	IRIS
Cobalt	6.0E-02	NCEA	NA		NA		NA	
Copper	4.0E-02	NCEA	4.4E-03	Gradient 2000	NA		NA	
Iron	3.0E-01	NCEA	NA		NA		NA	
Lead	NA		NA		NA		NA	
Manganese	4.7E-02	IRIS	1.4E-05	IRIS	NA		NA	
Mercury	3.0E-04	IRIS	8.6E-05	IRIS	NA		NA	
Molybdenum	5.0E-03	IRIS	NA		NA		NA	
Nickel	2.0E-02	IRIS	NA		NA		NA	
Selenium	5.0E-03	IRIS	NA		NA		NA	
Silver	5.0E-03	IRIS	NA		NA		NA	
Thallium	8.0E-05	IRIS	NA		NA		NA	
Vanadium	9.0E-03	IRIS	NA		NA		NA	
Zinc	3.0E-01	IRIS	NA		NA		NA	

*NA = Not available.

Notes

Cadmium oral RfD is based on administered dose in food, not water.

Chromium toxicity values reflect assumed 6:1 ratio of CrIII to CrVI.

Mercury as mercuric chloride (oral) or elemental (inhalation).

Thallium as thallium sulfate, chloride, or carbonate.

Vanadium as vanadium pentoxide.

Sources

IRIS: EPA's Intergrated Risk Information System, www.epa.gov/iris/

HEAST alt: EPA's Health Effects Assessment Summary Tables, alternate values, 1997 Update

NCEA: EPA's National Center for Environmental Assessment; provisional toxicity values

Gradient 2000. 'Human Health Risk Assessment, Hurley Soils Investigation Unit, Volume 1', Prepared for New Mexico Environment Department by Gradient Corporation, Cambridge, MA, February 22, 2000.

ATTACHMENT 2

Wilcoxon Signed Rank Tests

Testing Differences with Particle Size

Comparisons of concentrations with particle size, using <250 and 250–2000 fractions. The data source includes reaches P-1, P-2, P-3. The analytes investigated are As, Fe, Mn, Zn, Pb, and Cu. The features investigated are overbanks, bars, and active channel.

Overbank Surface Samples

As overbank surface point samples
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 2.9983, p-value = 0.0027
alternative hypothesis: true mu is not equal to 0

Fe overbank surface point samples
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 3.8033, p-value = 0.0001
alternative hypothesis: true mu is not equal to 0

Mn overbank surface point samples
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 1.0065, p-value = 0.3142
alternative hypothesis: true mu is not equal to 0

Zn overbank surface point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 179, n = 19, p-value = 0.0002
alternative hypothesis: true mu is not equal to 0

Pb overbank surface point samples
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 2.8776, p-value = 0.004
alternative hypothesis: true mu is not equal to 0

Cu overbank surface point samples
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 3.7839, p-value = 0.0002
alternative hypothesis: true mu is not equal to 0

Testing Differences with Particle Size

Overbank Deep Samples

As overbank depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 40, n = 11, p-value = 0.5771
alternative hypothesis: true mu is not equal to 0

Fe overbank depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 60, n = 11, p-value = 0.0137
alternative hypothesis: true mu is not equal to 0

Mn overbank depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 30, n = 11, p-value = 0.8311
alternative hypothesis: true mu is not equal to 0

[redacted] overbank depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 59, n = 11, p-value = 0.0186
alternative hypothesis: true mu is not equal to 0

Pb overbank depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 35, n = 11, p-value = 0.8984
alternative hypothesis: true mu is not equal to 0

Cu overbank depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 66, n = 11, p-value = 0.001
alternative hypothesis: true mu is not equal to 0

Testing Differences with Particle Size

Bar Surface Samples

As Bar surface point samples
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 3.4008, p-value = 0.0007
alternative hypothesis: true mu is not equal to 0

Fe surface point samples
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 3.8048, p-value = 0.0001
alternative hypothesis: true mu is not equal to 0

Mn surface point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 145, n = 19, p-value = 0.0446
alternative hypothesis: true mu is not equal to 0

[illegible] surface point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 190, n = 19, p-value = 0
alternative hypothesis: true mu is not equal to 0

Pb surface point samples
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 2.8776, p-value = 0.004
alternative hypothesis: true mu is not equal to 0

Cu surface point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 190, n = 19, p-value = 0
alternative hypothesis: true mu is not equal to 0

Testing Differences with Particle Size

Bar Deep Samples

As Bar depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 57, n = 11, p-value = 0.0322
alternative hypothesis: true mu is not equal to 0

Fe Bar depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 66, n = 11, p-value = 0.001
alternative hypothesis: true mu is not equal to 0

Mn Bar depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 56, n = 11, p-value = 0.042
alternative hypothesis: true mu is not equal to 0

[redacted] Bar depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 64, n = 11, p-value = 0.0029
alternative hypothesis: true mu is not equal to 0

Pb Bar depth point samples
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 2.891, p-value = 0.0038
alternative hypothesis: true mu is not equal to 0

Cu Bar depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 60, n = 11, p-value = 0.0137
alternative hypothesis: true mu is not equal to 0

Testing Differences with Particle Size

Active Channel Surface Samples

As Active channel surface point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 66, n = 11, p-value = 0.001
alternative hypothesis: true mu is not equal to 0

Fe Active channel surface point samples
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 2.891, p-value = 0.0038
alternative hypothesis: true mu is not equal to 0

Mn Active channel surface point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 53, n = 11, p-value = 0.083
alternative hypothesis: true mu is not equal to 0

Ni Active channel surface point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 66, n = 11, p-value = 0.001
alternative hypothesis: true mu is not equal to 0

Pb Active channel surface point samples
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 2.891, p-value = 0.0038
alternative hypothesis: true mu is not equal to 0

Cu Active channel surface point samples
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 2.891, p-value = 0.0038
alternative hypothesis: true mu is not equal to 0

Testing Differences with Particle Size

Active Channel Deep Samples

As Active channel depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 45, n = 11, p-value = 0.3203
alternative hypothesis: true mu is not equal to 0

Fe Active channel depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 66, n = 11, p-value = 0.001
alternative hypothesis: true mu is not equal to 0

Mn Active channel depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 60, n = 11, p-value = 0.0137
alternative hypothesis: true mu is not equal to 0

Ni Active channel depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 65, n = 11, p-value = 0.002
alternative hypothesis: true mu is not equal to 0

Pb Active channel depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 66, n = 11, p-value = 0.001
alternative hypothesis: true mu is not equal to 0

Cu Active channel depth point samples
Exact Wilcoxon signed-rank test
signed-rank statistic V = 66, n = 11, p-value = 0.001
alternative hypothesis: true mu is not equal to 0

Testing Differences with Depth

Comparisons of concentrations with depth within a particle size, using <250 and 250–2000 fractions. The data source includes reaches P-1, P-2, P-3. The analytes investigated are As, Fe, Mn, Zn, Pb, and Cu. The features investigated are overbanks, bars, and active channel.

Overbanks, <250 µm Samples

As overbanks <250 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 58, n = 11, p-value = 0.0244
alternative hypothesis: true mu is not equal to 0

Fe overbanks <250 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 34, n = 11, p-value = 0.9658
alternative hypothesis: true mu is not equal to 0

Mn overbanks <250 µm fraction
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 1.157, p-value = 0.2473
alternative hypothesis: true mu is not equal to 0

Zn overbanks <250 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 55, n = 11, p-value = 0.0537
alternative hypothesis: true mu is not equal to 0

Pb overbanks <250 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 64, n = 11, p-value = 0.0029
alternative hypothesis: true mu is not equal to 0

Cu overbanks <250 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 62, n = 11, p-value = 0.0068
alternative hypothesis: true mu is not equal to 0

Testing Differences with Depth

Overbanks, 250–2000 µm Samples

As overbanks 250–2000 µm fraction
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 2.848, p-value = 0.0044
alternative hypothesis: true mu is not equal to 0

Fe overbanks 250–2000 µm fraction
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 0.623, p-value = 0.5333
alternative hypothesis: true mu is not equal to 0

Mn overbanks 250–2000 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 42, n = 11, p-value = 0.4648
alternative hypothesis: true mu is not equal to 0

[redacted] overbanks 250–2000 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 56, n = 11, p-value = 0.042
alternative hypothesis: true mu is not equal to 0

Pb overbanks 250–2000 µm fraction
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 2.4907, p-value = 0.0127
alternative hypothesis: true mu is not equal to 0

Cu overbanks 250–2000 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 57, n = 11, p-value = 0.0322
alternative hypothesis: true mu is not equal to 0

Testing Differences with Depth

Bars, <250 µm Samples

As Bars <250 µm fraction
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 1.8681, p-value = 0.0618
alternative hypothesis: true mu is not equal to 0

Fe Bars <250 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 34, n = 11, p-value = 0.9658
alternative hypothesis: true mu is not equal to 0

Mn Bars <250 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 35, n = 11, p-value = 0.8984
alternative hypothesis: true mu is not equal to 0

Hg Bars <250 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 32, n = 11, p-value = 0.9658
alternative hypothesis: true mu is not equal to 0

Pb Bars <250 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 44, n = 11, p-value = 0.3652
alternative hypothesis: true mu is not equal to 0

Cu Bars <250 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 45, n = 11, p-value = 0.3203
alternative hypothesis: true mu is not equal to 0

Testing Differences with Depth

Bars, 250–2000 µm Samples

As Bars 250–2000 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 56, n = 11, p-value = 0.042
alternative hypothesis: true mu is not equal to 0

Fe Bars 250–2000 µm fraction
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = -0.3113, p-value = 0.7555
alternative hypothesis: true mu is not equal to 0

Mn Bars 250–2000 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 25, n = 11, p-value = 0.5195
alternative hypothesis: true mu is not equal to 0

Ni Bars 250–2000 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 33, n = 11, p-value = 1
alternative hypothesis: true mu is not equal to 0

Pb Bars 250–2000 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 52, n = 11, p-value = 0.1016
alternative hypothesis: true mu is not equal to 0

Cu Bars 250–2000 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 45, n = 11, p-value = 0.3203
alternative hypothesis: true mu is not equal to 0

Testing Differences with Depth

Active Channel, <250 µm Samples

As Active channel <250 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 49, n = 11, p-value = 0.1748
alternative hypothesis: true mu is not equal to 0

Fe Active channel <250 µm fraction
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = -2.7576, p-value = 0.0058
alternative hypothesis: true mu is not equal to 0

Mn Active channel <250 µm fraction
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = 1.1119, p-value = 0.2662
alternative hypothesis: true mu is not equal to 0

Ni Active channel <250 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 46, n = 11, p-value = 0.2783
alternative hypothesis: true mu is not equal to 0

Pb Active channel <250 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 17, n = 11, p-value = 0.1748
alternative hypothesis: true mu is not equal to 0

Cu Active channel <250 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 38, n = 11, p-value = 0.7002
alternative hypothesis: true mu is not equal to 0

Testing Differences with Depth

Active Channel, 250–2000 µm Samples

As Active channel 250–2000 µm fraction
Wilcoxon signed-rank test
signed-rank normal statistic with correction Z = -1.4699, p-value = 0.1416
alternative hypothesis: true mu is not equal to 0

Fe Active channel 250–2000 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 0, n = 11, p-value = 0.001
alternative hypothesis: true mu is not equal to 0

Mn Active channel 250–2000 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 59, n = 11, p-value = 0.0186
alternative hypothesis: true mu is not equal to 0

Ni Active channel 250–2000 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 52, n = 11, p-value = 0.1016
alternative hypothesis: true mu is not equal to 0

Pb Active channel 250–2000 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 24, n = 11, p-value = 0.4648
alternative hypothesis: true mu is not equal to 0

Cu Active channel 250–2000 µm fraction
Exact Wilcoxon signed-rank test
signed-rank statistic V = 25, n = 11, p-value = 0.5195
alternative hypothesis: true mu is not equal to 0